iTutorials for the Aid to Mild Cognitively Impaired Elderly Population in their Preferred Environment

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Jury

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Abstract

In the context of Assistive Technologies (AT), the present work addresses the improvement and greater adaptability of *iTutorials*, a supportive system we have been working on over the last two years, and which is intended to provide in-home support to cognitively impaired older adults in the performance of Activities of Daily Living (ADLs).

The new approach to *iTutorials* resulted in a more adaptive system addressing, on the one hand, activity guidance based on the actual context and the user profile, and on the other hand, the design of an interactive interface tailored to the user needs in an attempt to mitigate the physical decline and memory loss affecting our target users. The agent-based architecture of *iTutorials* deploys a distributed system that allows caregivers to enter and manage data from a different device than the touch-screen computer where the user interface runs. Empiric results obtained while testing with real Portuguese older volunteers demonstrated that our application is easy to learn and pleasant to use, and proved its aid to elderly users with cognitive disabilities in the accomplishment of basic tasks.

Keywords

Assistive Techonologies (AT)

Activities of Daily Living (ADLs)

Human-Computer Interaction (HCI)

Intelligent Agents (IA)

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1 Introduction

1.1 Motivation

Comforting and caring for elder citizens, especially those affected by cognitive impairments, is a societal obligation and a challenge that becomes critical as our population rapidly ages. Elderly people will likely account for 30% of the EU population by 2060, in comparison to the 17.2% in 2009. Average life expectancy in the EU is one of the highest in the world. In 2030, life expectancy at birth is expected to rise to 85.3 years for women and 80.0 years for men (Eurostat, 2010).

On the one hand, increasing longevity and increasing survival to acute diseases implies a growth in the prevalence of chronic disabilities. Diverse conditions can be often combined with different severity, impairing individuals' autonomy and worsening their quality of life (Annicchiarico et al., 2008). On the other hand, elderly people account for a high percentage of institutionalization, generating substantial expenses on medical assistance to EU governments. Social services are placed under considerable pressure since hospitalization is often not related to the acute medical condition of the elders but to their need of care and social support (Wilcox et al., 1994). Clearly, societal resources are not seen to be sufficient to assist all impaired older adults, and while human care cannot and will not be replaced, new alternatives need to break through. In this context, the use of *iTutorials (interactive Tutorials)* as a supportive system providing procedural guidance on how to perform in-home Activities of Daily Living (ADLs) is expected to enhance elders' self-dependence. In particular, our present work approaches the concept of ***supported autonomy***, which refers to the possibility for elders to remain living comfortably in their preferred environment while being supported by Assistive Technologies (AT).

There are also personal circumstances that motivated me to continue working on *iTutorials* for my Master's thesis. While studying at *Instituto Superior Técnico*, one of the courses taken as part of the mobility program was Human-Computer Interaction (HCI), that proved to be very profitable and interesting. Since I had no prior experience in the field, I decided to focus on the design of a more usable interface, which was actually one of the shortcomings that *iTutorials* presented. The user interface was integrated with agent-based technology in order to customize the application, and its design was iteratively improved through evaluation with end-users so that usability problems were resolved promptly. Hence, the deployment of such a system became a remarkable challenge.

1.2 Previous work

The conception of *iTutorials* was born under *SHARE-it* (Supported Human Autonomy for Recovery and Enhancement of cognitive and motor abilities using Information Technologies), an EU FP6 funded project which addressed the development of a scalable, adaptive system of add-ons to sensor and AT to be modularly integrated into an intelligent home environment to enhance the individual's autonomy (SHARE-it, 2007). The final architecture of *SHARE-it* was composed by a conjunction of different elements such as sensor networks, robotic platforms or a Multi-Agent System (MAS).

The design and deployment of *iTutorials* was motivated by the necessity of providing alternatives to the constant care demanded in assisting cognitively impaired elderly patients with depleted self-dependence on a daily basis. Our system essentially addressed activity guidance through a series of pre-defined instructions in sequence supported by visual and auditory cues. It was designed to be displayed on a touch-screen, normally attached to the elders' wheelchair or walker for greater mobility.

Two different key factors tackled adaptability in the previous version of *iTutorials*: (1) the user profile defined by doctors; (2) the users' actual location, which was perceived by a sensor network. These two aspects were approached by the MAS, whose agents interacted and collaborated among themselves obtaining data from other elements within *SHARE-it*. The *Environment Agent* perceived the current location of the user through the sensor network, while the *Patient Agent* was responsible for all the functions related to ADLs, such as scheduling activities or selecting the suitable tutorials for guidance.

The testing phase within the *SHARE-it* project (Rubio, 2010) helped to identify some hindrances that prevented the previous version of *iTutorials* from becoming more flexible and adaptive to the user needs, giving no attention to their particular limitations:

- The **design of the previous user interface** (developed by another partner university under the *SHARE-it* project) precluded to accommodate the users' preferences, since interaction was just focused on providing a static sequence of guidelines regardless of any particular context. The interface mainly failed to provide information about the system status or any navigation reference, used too many technicalities and poorly descriptive components, employed wrong colouring and font size, and offered no way to recover from errors.
- Some of the **ADLs supported by a tutorial** might lead to undesirable situations difficult to alleviate or control (*e.g.* the user burns food while cooking), and so they were not suitable for tutoring cognitively impaired older adults.
- The **previous user profile** failed to consider high prevalence conditions affecting our target population such as *diabetes* or *hypertension* but acknowledged other medical descriptors that were too generalist.

1.3 A new approach to iTutorials

Considering the shortcomings of the previous work on *iTutorials*, this new version approaches a User-Centered Design (UCD) to obtain a system that:

- **meets the user needs.** Information about the habits and routines of our target users is gathered in order to determine which tasks could be usefully supported by a tutorial.
- **improves usability.** It is necessary to model the content of the tutorials in the likeness of the mental model that users keep in mind when performing any daily routine so that they are easy to follow.
- **considers the knowledge that caregivers have.** An interface for caregivers was developed so that their knowledge about how users like to perform daily routines helps to pattern the tutorials suitably.
- **redefines the user profile.** The user profile needs to address not only those degenerative conditions that widely affect our target users and are likely to worse over time, but also those age-related metabolic derangements that seriously compromise elders' quality of life.
- **accommodates the user preferences.** The new user interface needs to tackle functionalities that range from giving procedural instructions and asking questions about preferences to provide explanations and comfort users along any tutorial. Answers obtained from inquiring users help to pattern the next steps of a tutorial.
- **enhances the concept of *supported autonomy*.** Users are offered on-line help and ways of recovering from errors, so that no constant supportive intervention from caregivers is needed.

The behaviour of several sub-components that the previous work of *iTutorials* had encompassed, such as the MAS or the communication mechanism to connect the agent with the user interface, were redesigned within this version in order to accommodate the new approach.

1.4 Objectives

This version of *iTutorials* pursues to attain the following goals:

1. To correct the usability problems and improve the functionality of the previous version of *iTutorials* in order to ease activity guidance.
2. To examine the suitability of a touch-based interactive interface tailored to the actual needs of users as part of *iTutorials*.

3. To reduce the heavy dependence older adults have in caregivers by focusing their intervention on supervising that elders perform their basic routines successfully.

4. To promote the integration of AT with traditional care services for the elders in order to diminish much of the technological rejection.

5. To reinforce the residual abilities of cognitively impaired elderly population through the performance of in-home ADLs.

1.5 Outline

The first part of this document is intended to give readers a general idea of our present work and its extension. Chapter **Introduction** defines the purpose and scope of *iTutorials*, followed by a brief summary of the previous work on the *SHARE-it* project and the new objectives to pursue. Chapter **State-of-the-art** introduces the level of development in the field of AT regarding supportive systems that provides activity guidance to individuals with compromised cognitive abilities.

The second part of the document addresses the key features that characterize *iTutorials*. Chapter **Specification** focuses on analysing the requirements, describing the target users and their needs. Chapter **Design** is intended to define the conceptual model and the activity work-flows as well as the specification for the user profile.

The third part of the document describes how *iTutorials* was initially envisioned as a prototype and later implemented while actively involving end-users and experts for feedback. Chapter **Prototyping** addresses an initial paper design of the storyboards and the building of a low-fidelity prototype. Chapter **Implementation** describes the technologies used for the development and the media resources employed for recording the auditory and visual cues.

The last part of this document is focused on describing thoroughly how the experimentation phase ran, which were the outcomes obtained and how deviations were handled. Chapter **Testing** explains the methodology used for testing our system and analyses the results at a technical and functional level. Chapter **Conclusions** gives some concluding remarks and draw foreseeable future lines of research.

2 State of The Art

2.1 Activity guidance

For nearly 25 years, researchers have been devising and developing AT to help caring elders with chronic degenerative diseases on a daily basis. Early interventions of **supportive systems** provided guidance through daily activities by combining pictorial instructions with auditory or tactile cues. COGORTH (from COGnitive ORTHotics) are software-based personal reminder systems for cognitively impaired people that allow to program sequential messages to be displayed as textual, audio or visual cues (Levine & Kirsch, 1985). These cues can be used to provide information about how to complete an activity, to correct errors on proceedings, to manage interruptions from higher important tasks, and to perform multiple activities concurrently as figure 2.1 depicts. A significant example of cognitive orthotics is PEAT (Planning and Execution Assistant and Training), a hand-held cognitive orthotic device for individuals with brain injury to automatically generate daily plans, correct schedule problems when necessary and guide users through multi-step procedures (Levinson, 1997). PEAT enables users to complete more activities on time with less help and also provides a virtual caregiver 24 hours per day. However, it fails to accommodate the needs of elder users regarding their visual and hearing acuity and motor abilities on such tiny devices as Personal Digital Assistants (PDAs). PEAT neither acknowledges the cognitively worsening that end-users experience over time in order to redefine its user model.

There are a wide range of cases to give example of successful use of aids to complete the realization of specific tasks. Some researchers have demonstrated the effectiveness of activity guidance systems based on dynamic illustrations and icons to follow the steps of a recipe (Steele et al., 1989) and also on the performance of personal care tasks such as shaving (Pagadala & Napper, 1994). COACH (Cognitive Orthosis for Assisting aCtivities at Home) is another activity guidance system which takes advantage of Bayesian filtering techniques. This supportive environment is mainly aimed at users affected by dementia and based on prompting. It uses a personal computer and a video camera to unobtrusively track users during the performance of ADLs. By the use of Bayesian filtering techniques to estimate how tasks progress, COACH provides pre-recorded cues to the user when necessary, minimizing their dependence on caregivers (Mihailidis et al., 2001).

Another system which also uses AI technologies as well as **tutoring techniques** is MAPS (Memory Aiding Prompting System), which breaks down a task into constituent parts and uses images and verbal instructions for prompting each step. MAPS project provides an environment in which caregivers can create scripts to be used by users with cognitive disabilities, so that the system is manually personalized (Carmien, 2002). The application is strongly based on hardware: a PDA provides a *panic button* as an error correction functionality, while a PC based application provides tools for script creation and modification as figure 2.2 depicts.

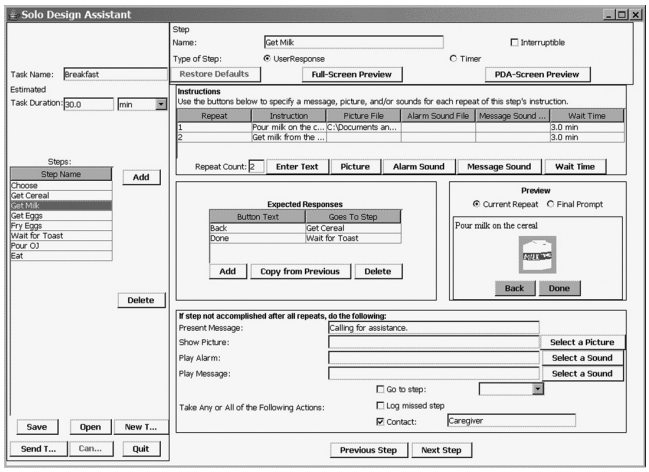

Figure 2.1: COGORTH. User interface for entering task information

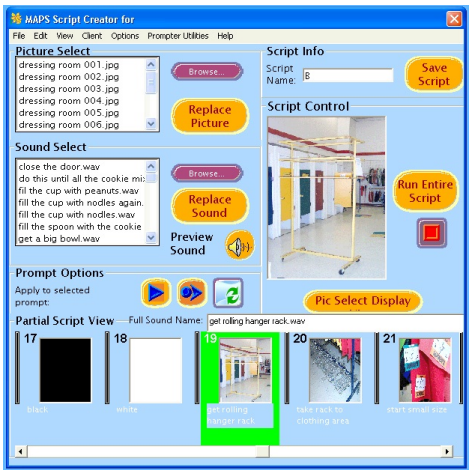

Figure 2.2: MAPS. Script design environment

CASIS (Context-Aware Service Integration System) is a good example of how convenient **agent-based technology** is for the development of assistive living applications. CASIS is an event-driven service-oriented and MAS framework whose goal is to provide context-aware healthcare services to the elderly resident in a smart home. CASIS framework allows remote caretakers to closely monitor and attend to the elder well-beings. Connecting all caring services together in a service-oriented framework, CASIS is able to infer the status of the elder and performs appropriate actions (Wan-rong et al., 2006).

In the exploration of the benefits that **independent living technologies** have on older adults living in-home, researchers have evaluated the life cycle of independent living technologies within TRIL (Technology Research for Independent Living) Center. A number of supportive technologies and sensory systems are deployed in the homes of the elderly to collect physiological, environmental and computational context data for clinical study into social connectedness and cognitive function of older adults (G-Doherty & Quigley, 2009). Such type of researches resulted in positive conclusions about the potential of in-home assistive technologies for the elders to continue living in their homes as they age.

2.2 Accommodative user interfaces

Although this new approach to *iTutorials* does not pursue user modelling since it is unable to track the user during all the tutorial performance, the present work approaches the concept of distributed environment such as in-home locations. Innovative emotional strategies for a better HCI on the context of supportive systems have been recently described in (Chaffar & Frasson, 2010). A very relevant work in accommodative user interfaces on the context of ADLs applied to mild dementia care have been reported in (Biswas et al., 2010). The main contribution of this work is an approach for system building that incorporates activity monitoring, user interface plasticity and scenario verification targeting people with cognitive decline.

The challenge that represents designing interfaces aimed at older people with significantly different and dynamically changing needs is tackled in (Gregor et al., 2002). This work introduces a new design paradigm and suggests a methodology to assist its achievement, user sensitive inclusive design. Usability experiments to assess the suitability of different assistive user interfaces are presented in (Sutcliffe et al., 2003). The interfaces differed in the level of support provided for the user and complexity of facilities for composing e-mail messages. Usability evaluation demonstrated that no one interface was superior because of individual differences in usability problems, and reaffirmed the need for interface customization when targeting cognitively disabled users.

Results on the reception and truly benefit of accommodative interfaces in the life of urban older adults are discussed in (Bickmore et al., 2005). This study examines the acceptance and usability of a conversational agent that interacts with older adults on a touch-screen computer installed in their homes. Most users found the agent very easy to interact with, even though many of them had little or no previous experience using computers. Similarly, a study on the suitability of a touch-based interface for elderly users is presented in (Häikiö et al., 2007). This work is based on the user of a mobile phone to enable home-dwelling elderly people to choose their meals to be delivered by a home care service. Results showed that the touch-based user interface was easy to learn and adopt by elders regardless of their physical or cognitive weaknesses.

The potential of accommodative interfaces in regards to older users is presented in (Sloan et al., 2010), discussing the difficulties in matching people with less severe, but multiple, impairments with the most appropriate accessibility features at a given time, and exploring the role of automated or semi-automated adaptations. A binocular view of users' interaction with supportive systems regarding the large repertoire of methods for designing systems that meet usability principles have been tackled in (Jameson et al., 2009). An introduction to methodologies for evaluating usable interfaces is presented in (Spaulding & S.Weber, 2009) and on a long-term vision in (Gruding, 2009). The discussion is organised around three types of activity: understanding user needs, interaction design and iterative evaluation.

2.3 Aging Human Factors

This section explores the state-of-the-art in the implications of aging for interface design, that is, to know the capacities and limitations of cognitively impaired elders, how they perceive the surrounding world, store information, react to stimuli and resolve problems.

2.3.1 Vision and hearing

Vision and hearing relate to the *sensory stimuli*, whose perception becomes compromised for the elders. Interfaces that use sound to catch the attention of older adults require lower frequency sounds. Recorded voice should make use of speakers with low pitched voices (Gregor, 2001). Findings on visual search support design recommendations emphasizing layout simplicity, clarity and consistency. Older readers may benefit from negative screen contrast (light background, dark text), sans-serif fonts that are in the 10-14 point range, short line lengths and left justified text. Overuse of capital words must be prevented as it might hinder text recognition (Hawthorn, 2007). Designs should maintain the use of boxes and lines to separate content, while white spaces are recommended for balancing clarity and separating options (Fisk et al., 2009).

Colour shadings that convey information should be distinct, with a brightness increase and avoidance of blue tones. Colouring should be restricted to 8 colours, limiting codification to a palette of 4 different colours. Complementary colours (*e.g.* yellow and blue) appear to be rather suitable than adjacent colours (MacDonald, 1990). Designs for older adults should use only simple, highly relevant graphics and avoid decorative animation and pictures, wallpaper patterns and flashing text. Changes in the system status should also be marked out by alternating colours, using them according to convection (*e.g.* red to stop, green to go ahead) (Hawthorn, 2000).

2.3.2 Psycho-motor abilities

Any move towards interaction that is machine paced rather than self paced may cause problems for older users. They may also have difficulty in receiving new information during the execution of movements. Therefore, older users should be warned to first focus on understanding instructions before acting accordingly. Plus, no complete response is expected within a given time for preventing users from feeling pressured. Designs should avoid exposing the elders to many choices, since findings indicate that elderly people would move more slowly (Fisk et al., 2009).

2.3.3 Attention and memory

Older adults have problems maintaining attention over long periods of time (Fisk et al., 1997). Hence, tasks might be divided into different subtasks or steps, so that each can be associated to a particular screen. Long-term memory involves several components of interest: *episodic memory* for specific events, and *procedural memory* for holding knowledge of the way in which tasks are carried out. Researches state that findings of age-related limitations in both types of memory are common, showing noticeable decline in the ability to perform tasks simply involving recognition of items from previous exposure, and significant decline in the ability to recall content (Hoyer et al., 1999). Age is also the cause of the steep decline in the numbers of items which can be held in *short-term memory*, being around 5 items for adults between their sixties and seventies (Botwinick, 1984).

3 Specification

A key principle in UCD regarding supportive systems is that the design should be based on a detailed understanding of the needs of users. This chapter aims to establish the requirements of *iTutorials* by characterizing the target users and the functions they demand.

3.1 Target Population

Typical users of *iTutorials* are defined as elderly patients with cognitive disabilities on a *mild* or *moderate* degree, affected by co-morbid conditions such as sensory disorders or memory loss, and physical decline leading to a defective self-dependence. Users might also be simultaneously affected by metabolic derangements and chronic conditions such as *high cholesterol*, *hypertension*, *osteoporosis* or *diabetes*.

Next subsections summarize the symptoms and impaired functions of the different types of disability affecting target users. Please refer to appendix A for a glossary of medical terms.

3.1.1 Cognitive Impairment

- **Mild degree disability**. People suffering from mild cognitive impairment, like mild dementia, show an impaired performance at remembering where they put important objects, which might be dangerous in certain situations. They face difficulties in identifying landmarks and might get lost in new situations. Supervision might be required in case of behavioural disturbances (Cortés et al., 2007).

- **Moderate degree disability**. People suffering from moderate cognitive impairment experience difficulties in facing simple tasks. They show a decreased performance in ADLs such as eating or dressing, therefore they might need assistance in order to remind some steps. Although their sense of time and speed could be lost, they might experience an overwhelming need of walking (Cortés et al., 2007).

Disability	Cognitive Impairment	
Disease	Dementia [1] [2]	
Symptom	**Impaired Function**	**Degree**
Memory loss	Long-term memory	Mild and Moderate
Spatial disorientation	Visuo-spatial abilities	Mild and Moderate
Apraxia	Executive functions and judgement	Mild
Wandering	Behaviour	Moderate

Table 3.1: Impaired functioning for mild and moderate cognitive disability

3.1.2 Mixed Impairment

Although *iTutorials* is largely focused on supporting the cognitive limitations of the elders, physical disabilities resulting onto mixed impairment simultaneously affect their functioning.

- **Mild degree disability**. People suffering from mild mixed impairment normally walk with a support. They show some decline in regard to their logical abilities, being able to decide what they want but undecided on how to obtain it. They often face difficulties in recognizing objects, faces and written words. Although they understand quite well spoken language, their speech might be compromised (Cortés et al., 2007).
- **Moderate degree disability**. People suffering from a moderate mixed impairment are not able to walk. They experience significant memory loss to the point of not remembering where their bed is. Their judgement could be compromised, facing difficulties in executing simple tasks. They might be unable to speak but able to understand simple spoken instructions (Cortés et al., 2007).

Disability	Mixed Impairment	
Disease	Post-stroke	
Symptom	**Impaired Function**	**Degree**
Hemiparesis	Mobility	Mild
Hemiplegia	Mobility	Moderate
Apraxia	Mobility	Moderate
Memory loss	Short and long-term memory	Moderate
Neglect	Attention	Mild and Moderate
Visual agnosia	Recognition	Mild and Moderate
Motor aphasia	Language	Mild
Mixed aphasia	Language	Moderate

Table 3.2: Impaired functioning for mild and moderate mixed disability

[1] Dementia occurs in the advanced stages of Parkinson.
[2] Alzheimer is also called senile dementia of the Alzheimer type.

3.2 Actors

Defining the actors of our system is defining its boundaries, since actors are usually the initiators of interaction flows that define the behaviour of *iTutorials*. We have defined two primary actors, *users* and *caregivers*, and one secondary actor, *doctors*. The *environment* plays an off-stage role, since it enhances the system performance by providing contextual information. Figure 3.1 shows the different procedures by which actors may interact with *iTutorials*.

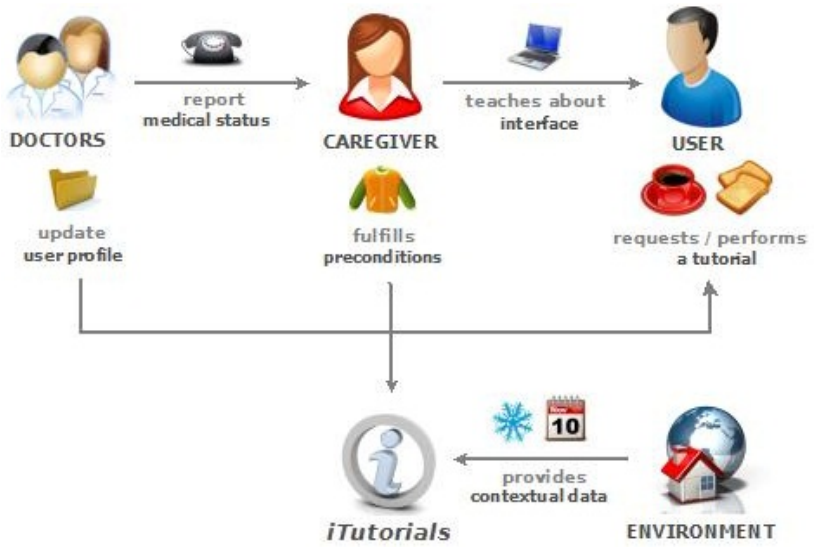

Figure 3.1: Interaction flows among actors and *iTutorials*

3.2.1 Users

Users are those actors to whom the system is addressed. As referred in section 3.1, a typical user is a cognitively impaired elder with mild functional disabilities generally leading to a decline of his/her autonomy. Elders usually have no prior technological experience, which may arouse certain reluctance to use supportive systems. Hence, the role of end-users is focused on interacting with the system to perform any of the stepwise tutorials, either when they are set by caregivers or when explicitly requested by the user.

3.2.2 Caregivers

One of the main goals of *iTutorials* is to reduce the potential dependence elderly people has in their caregivers. The lack of autonomy that elders have often lead into a double side-effect: the increased

workload for caregivers when continuously assisting elders, and the ensuing lack of self-dependence affecting users even in the performance of simple routines.

Two type of caregivers are addressed: those who are elders' close relatives (informal caregivers) and those who are professionals paid by institutions to provide assistance and caring service (formal caregivers). Regarding *iTutorials*, caregivers are provided with an interface to enter information about users given the following competences that their role demand:

- *Activity preconditions.* Complying with the activity requirements in order to guarantee its proper functioning. For instance, caregivers are responsible for arranging all the items necessary for preparing a sandwich on the kitchen counter.
- *Selection of items.* Choosing the items that the user will use along the tutorial performance, so that a certain interaction flow how to guide the user through the activity can be modelled. For instance, the user normally wears a coat instead of a jacket during wintertime.
- *Technological training.* Introducing users to the user interface for training, so that the elderly get to know how it works before running any tutorial. Much of the rejection that AT experience is due to the additional effort elders believe that its use requires, as these technologies do not fit into the process of care. Hence, users should get familiar with *iTutorials* in order to perceive it as beneficial, in spite of their technophobia or computer illiteracy.

3.2.3 Doctors

Doctors are responsible for monitoring users in order to make a complete evaluation of their physical abilities and cognitive functions over time. Functional assessments about the elders' medical status must be reported to their respective caregivers, so that they can work together with doctors to review the necessary adjustments. Changes in the acuteness of the conditions affecting the users might compromise their responsiveness in terms of interaction. Therefore, doctors are responsible for updating the user profile so that the user interface can be attuned accordingly.

3.2.4 Environment

The environment encompasses all the data that allow to have actual information about the user context. Such knowledge is very necessary for *iTutorials* in order to make decisions based on the circumstances, such as patterning the appropriate sequence of steps for a tutorial according to the current climate. Please refer to section 4.4 for further aspects on how contextualization is approached.

3.3 Activities of Daily Living

Along the design of the previous version of *iTutorials*, we had the opportunity to be assisted by caregivers and doctors when evaluating the most appropriate routines for our target population. Furthermore, we got to prove their suitableness during the experimental phase with elderly volunteers (Rubio, 2010). We can conclude from our previous experience that some of the activities then considered for tutoring (cooking and personal hygiene) are actually not suitable for our target users mainly because of two reasons:

1. **Complex infrastructure.** The infrastructure needed for its performance is too complex and significantly variable from one habitat to another, which might lead to dangerous situations for the elders. Cooking routines are then dismissed due to the risk their performance involves (*e.g.* to get burned).

2. **Inappropriate environment.** The environment where the routine is contextualized is not adequate for the user to feel comfortable during its performance. Hence, those activities to be executed in the bathroom are neither adequate for *iTutorials* since users may be reluctant to use assistive devices in such an intimate environment.

In order to determine which ADLs might be actually suitable to be supported by a procedural tutorial within this new version of *iTutorials*, two types of activities were considered: primarily, those necessary tasks for fundamental functioning consisting on self-care routines such as dressing; secondly, those activities to be performed on a regular basis by most individuals while being in their preferred environment, such as using the telephone or preparing food without cooking. Interviews with real caregivers also provided information about the most frequent tasks that our target users perform.

3.3.1 Preparing food

Preparing food is a daily routine to be performed several times a day in the kitchen. The following activities for *Preparing food* do not demand the user to cook at all so that the supervision of a caregiver is not constantly needed.

- *Preparing a sandwich*. This activity entails preparing a sandwich made of ham and cheese, normally spreading butter on both slices of bread. This task is generally performed for dinner or as a mid-afternoon snack.

- *Preparing a coffee*. This activity entails preparing a coffee without having to use a coffee maker. The user can choose to add sugar and/or milk to the coffee. Since taking coffee is a quite frequent activity, it can be performed routinely.

3.3.2 Dressing

Dressing is a daily routine to be performed several times a day in the bedroom, and which normally demands help from the caregiver. The performance of this activity might vary according to the user's gender and the current temperature. This category includes the following activities:

- *Dressing to go out*. This activity entails dressing up in order to leave the house, so that information about the temperature outdoors is relevant in order to properly help the user through the performance. Depending on how cold is outside, the user puts on different items of clothing: from a cardigan in spring to a jacket, a scarf, and gloves in cold winter. The user also takes an umbrella when the day is rainy.
- *Dressing for exercise*. This activity entails putting a tracksuit on as well as a pair of socks and trainers, so that the user is ready to exercise. Normally this is not a daily routine but an activity to be performed when necessary according to the training program defined for the user by doctors.
- *Putting the pyjamas on*. This activity entails putting the pyjamas on in order to go to sleep. This is a daily routine whose dynamics depends not only on how cold it is but also on the user's gender, since men might use a two-pieces pyjamas and women a nightgown.

3.4 Requirements Analysis

This section analyses how our target population currently execute the ADLs previously referred in section 3.3 in order to recognize their needs (Buhler, 1996). There is a list of 11-questions which help to acknowledge who are the end-users of the system (their personal features, habits, capacities, physical limitations, *etc.*), which are their objectives, and how they would perform the tasks and in which circumstances (Lewis & Rieman, 1993). The answers will be used to define the functional and non-functional requirements of *iTutorials* later in section 3.6.

3.4.1 Interviewing experts: the 11-questions survey

The following 11-questions were answered not only by resorting all the knowledge acquired in the past while working on the *SHARE-it* project (Rubio, 2010), but also by interviewing actual caregivers with 15 years of experience who are daily in touch with impaired elders.

The caregivers interviewed currently work at the public Portuguese institution *O Vigilante - Associação de Socorros Médicos* as part of *Instituições Particulares de Solidariedade Social (IPSS)*, which provides in-home daily care to individuals of our target population through the joint work of caregivers, social

workers, nutritionists, nurses, and doctors. Caregivers support the elderly in daily routines such as personal hygiene, in-home displacements, eating (at least breakfast and lunch), meal supply (dinner pack) and social support (walking outdoors, shopping). They are also in charge of the daily domestic cleaning and housework (washing clothes, ironing) (nursing homes, 2011).

1. Who is going to use the system?

   As referred in section 3.1, our target users are cognitively impaired older adults who suffered from a stroke or were diagnosed with dementia. They might also suffer a significant decline of their motor abilities. Target users are novice on the use of touch-screen computers, and with basic education. Most of them are literate but have no regular habit of reading regularly due to their cognitive impairments.

2. Which tasks are currently executed?

   There are two different set of tasks that users execute depending on their physical and cognitive status. All these activities are supported by caregivers so that elders have a low level of independence. On the one hand, there are those *self-care routines* that a person must perform everyday such as feeding themselves, bathing, dressing, toileting or walking. On the other hand, there are another set of tasks engaging multiple functions that focus on *general activities* that are important for independent living in a community such as making phone calls, shopping, housekeeping or preparing food.

3. Which tasks are desirable?

   As referred in section 3.3, the desirable activities are those which demand very few infrastructure and whose context do not compromise the performance of the user. *Self-care routines* may refer to personal hygiene or dressing, while *general activities* may include preparing food or exercising.

4. How are the tasks learned?

   The tasks are currently learned by either following the instructions caregivers give or by heart.

5. Where are the tasks performed?

   The tasks are performed in the preferred environment of the user, where normally there is mild ambient light and no disrupting noise. Tasks can be also performed at geriatric institutions, although there might be some ambient noise and a noticeable contrast of light.

6. Which are the relations between users and information?

   Users are aware of the activities planned to be performed throughout the day, since they feel more confident when knowing they are familiar with the tasks to perform. Elders are normally informed by their caregivers about the activities scheduled and the people who will be involved.

7. Which other instruments does the user have?
   Apart from the voice instructions provided by caregivers, the user might have at disposal illustrations on how to perform a certain task. All the necessary items for the user to execute the task are provided beforehand.

8. How do users communicate among them?
   Users are not suppose to interact between them when performing any task. However, they do normally interact with caregivers in order to know how to perform a certain routine and in which order.

9. How often are the tasks performed?
   Many of the activities are based on daily routines essential for fundamental functioning so that they are performed at least once a day. However, certain task which are not essential but necessary for reinforcing the autonomy of the elders (going for a walk, preparing food) are performed several times a week.

10. Which are the temporal restrictions imposed?
    Information about the routines of the elders is provided by doctors in agreement with caregivers, who track users more closely and therefore have the most reliable information about their needs. Since elders are expected to get worse over time, doctors need to promptly report on the changes affecting their medical profile so that routines are adapted accordingly.

11. What happens if something goes wrong?
    In case of any setback, users might decide to either correct the mistake or start over again so that they can perform the activity gently. Elders can also ask for help from caregivers.

3.5 Problem Scenarios

These scenarios trace a storyline based on the information obtained by the 11-questions on how users currently perform routines, but independently from the future solution. The following problem scenarios picture one or more actors from the previous figure 3.1 interacting directly or indirectly within a particular context (Dix et al., 2004).

3.5.1 Scenario 1: Claudia fancies a sandwich

- **User Definition:** Claudia is a 74 years-old lady who suffers from an early phase of *Alzheimer* and a disorder called *apraxia* that mildly affects her movements. These conditions prevent her from performing activities where precise motor coordination is required. Claudia also presents *high cholesterol*, so that any food containing high levels of fats is no longer included in her diet.

- **Narrative Scenario:** It is Saturday evening and Claudia is asked by her caregiver if she fancies a sandwich. Since she is starting to feel hungry, she moves into the kitchen and follows the instructions of her caregiver on how to place low-fat ham and cheese to make a sandwich, eventually wrapped in a napkin to be eaten.

3.5.2 Scenario 2: Pedro wants to have a coffee

- **User Definition:** Pedro is a 84 years-old elder affected by a moderate *senile dementia* and a mild *visual agnosia* that impairs him in recognising faces. He also suffers from *diabetes*, so any sugar intake should be minimized.
- **Narrative Scenario:** Since it is snack time in mid-afternoon, Pedro feels like having a coffee and therefore goes into the kitchen. His caregiver arranges all the items needed for him to prepare his coffee, and heats the milk for him to use. Pedro then follows the caregiver's instructions on how to pour hot milk, add two teaspoons of coffee to his favourite mug, and finally stir the drink up. Pedro is also told not to add sugar since his glucose is too high.

3.5.3 Scenario 3: Mario goes for a walk

- **User Definition:** Mario is a 76 years-old elder who suffers from an early phase of *Parkinson* affecting him with weak *tremors* and short-time memory loss. Since he is quite overweighted, morning walks are part of his daily workout.
- **Narrative Scenario:** It is a Sunday morning fall and Mario would like to go for a walk around the park nearby. This week doctors have evaluated his medical condition, and informed his caregiver that his tremors have worsened so that he is experiencing a moderate rigidity in his limbs. Since it is quite cold outside, Mario goes to his bedroom and follows the instructions of his caregiver. He is already dressed up so he only needs to change his shoes, dress his jacket, and put his scarf on. Due to his reported worsening, his caregiver neither asks him to button his jacket up nor to put the gloves by himself.

3.5.4 Scenario 4: Ana wants to go to bed

- **User Definition:** Ana is a 68 years-old elder who suffers from a mild *Alzheimer* and a language disorder called *aphasia*. She is also affected by *osteoporosis*, resulting in a hip fracture some months ago.
- **Narrative Scenario:** Ana is in her bedroom, willing to go to bed. Since she is not completely recovered from her hip fracture, she does not normally wear trousers. Her caregiver then arranges

her bedtime clothes and asks her to take her dress off. Then, Ana is guided on how to put the nightgown on as well as a pair of warm socks since the night is rather chilly.

3.5.5 Scenario 5: Ricardo goes for a work-out

- **User Definition:** Ricardo is a 72 years-old elder who suffers from a mild *dementia* resulting in periods of confusion and mood swings. He is also affected by *auditory agnosia*, which prevent him from recognising some sounds.
- **Narrative Scenario:** Ricardo normally works out on a regular basis with the assistance of a social worker as part of his wellness program. It is a warm summer morning and Ricardo needs to change his clothes for his training. Since Ricardo is already wearing a t-shirt, his caregiver arranges his track-suit and indicates him to take his trousers off. Then Ricardo is guided on how to put the trousers on. Finally, and since he is already wearing sport socks, his caregiver asks him to put his trainers on.

3.6 System Requirements

Along the process of determining the users' expectations for *iTutorials*, energies have been directed towards ensuring that the final application meets their demands rather than attempting to make their requirements fit the features of our system. The following list of *functional requirements* and *non-functional requirements* together describe the specific behaviour of our system by identifying what it requires to accomplish in order to meet the needs of caregivers and elderly users.

Requirement:	UPGRADEABLE USER PROFILE
Rationale:	Doctors and caregivers shall be able to update the user profile whenever it is needed.
Fit criterion:	When the user profile is successfully updated, the content of the tutorials is adjusted accordingly.

Requirement:	SELECTION OF ITEMS
Rationale:	When scheduling an activity, caregivers shall be able to choose the items to be used during its performance.
Fit criterion:	When caregivers select the specific items to handle during a tutorial, the application patterns a complete interaction flow accordingly.

Requirement:	TUTORIAL ACTIVATION UPON REQUEST
Rationale:	The system shall allow users to execute any of tutorials recommended for them to perform when they are willing to.
Fit criterion:	Users are able to execute any available tutorial.

Requirement:	TUTORIAL PERSONALIZATION
Rationale:	Tutorials shall be patterned according to the limitations of the user.
Fit criterion:	Tutorials are selected for display depending on the user profile and the amount of cognitive activity they engage.
Requirement:	ACCOMMODATION TO THE USER PREFERENCES
Rationale:	Activity work-flows shall be attuned to the preferences of the user.
Fit criterion:	Users encounter questions about their preferences in order to model the next steps of any tutorial.
Requirement:	ON-LINE HELP
Rationale:	The system shall provide on-screen help information.
Fit criterion:	The top bar of the application includes an active help button at any step.
Requirement:	TUTORIAL CANCELLATION
Rationale:	The system shall permit users to quit an ongoing tutorial.
Fit criterion:	The option menu of the interface includes a cancel button at any step.
Requirement:	VISIBLE NAVIGATION
Rationale:	The system shall let users know where they are.
Fit criterion:	Users are able to move forward or backward through a navigation table.

Table 3.3: List of functional requirements

Requirement:	LEARNABILITY
Rationale:	It is easy for users to complete a tutorial for the first time.
Fit criterion:	Users find the application supportive and easy to use. They do not need to have prior technological experience.
Requirement:	EFFICIENCY
Rationale:	Once users are familiar with the user interface, they perform a tutorial without much hesitation.
Fit criterion:	Users recover easily from the errors made while performing a tutorial.
Requirement:	SWIFTNESS
Rationale:	Requests from users (*e.g.* help button) shall be answered promptly.
Fit criterion:	Waiting time for response is inferior than 1.5 seconds. If more, feedback about the system status is reported to the user.
Requirement:	IN-HOME USE
Rationale:	The system is designed to be used at the users' home.
Fit criterion:	The equipment necessary to display *iTutorials* is suitable to be used in-home (kitchen, bedroom).
Requirement:	DATA INTEGRITY
Rationale:	The system shall avoid data inconsistencies related to the user profile which may eventually affect users.
Fit criterion:	The system is consistent with data at any time.

Table 3.4: List of non-functional requirements

4 Designing

Considering the system requirements previously obtained, we are now going to design an appropriate solution. Before pondering how *iTutorials* will be presented to end-users, it is needed to design what it is for the end-users by means of the *conceptual model*.

4.1 Conceptual Model

The conceptual model is a high-level description of how a system is organised and works. Its main objective is to develop the mental model users have when interacting with the system. Hence, it is needed to know what end-users are thinking and which objects and operations are using, so that the conceptual model expresses what end-users can eventually do through the interface and which concepts they need to know (Robinson et al., 2010).

4.1.1 Mental model for *iTutorials*

It is very important that there is a clear correspondence between the user's mental model and the designer 's conceptual model, otherwise the resulting application might be rather difficult to interact with, increasing the number of errors and the frustration of users. Because supportive systems often provide new capabilities, concepts not found in the tutorial domain often creep into the conceptual model. Therefore, additional concepts should be strongly resisted, and admitted into the conceptual design only when they provide high benefit and their cost can be minimized through good user-interface design (Card, 1995).

Table 4.1 resumes the general concepts for *iTutorials*, including their attributes and the actions that users can perform on each of those objects. As objects in the same task-domain (*Preparing food*, *Dressing*) share actions, they are organised in categories. This specialization might help end-users to comprehend the conceptual model more easily (Johnson & Henderson, 2002).

TUTORIAL CONCEPTS	
Category	**Objects and Attributes**
User	name, age, sex (*attribute:* male, female), caregiver
Caregiver	name, phone number
Daytime	morning, afternoon, evening, night
Weather	hot (*attribute:* min), warm (*attribute:* min, max), chilly (*attribute:* min, max), cold (*attribute:* max), rainy
Activity	name, location, step (*attribute:* guideline, question)
Step	video, audio, text, picture, keyword
Location	bedroom, kitchen
Actions	warn (caregiver), be (location), perform/execute, cancel, exit (activity)

PREPARING FOOD CONCEPTS	
Category	**Objects and Attributes**
Sandwich	bread (*attribute:* number of slices), butter, ham (*attribute:* number of slices), cheese (*attribute:* number of slices)
Coffee	liquid (*attribute:* type {milk, water}), soluble coffee, sugar
Utensils	plate, vacuum bottle, mug
Silverware	knife, dessert spoon
Actions	spread on, place on, add, stir up, pour

DRESSING CONCEPTS	
Category	**Objects and Attributes**
Clothing	pyjamas, t-shirt, trousers (*attribute:* fastener {button, zip}), dress (*attribute:* fastener {button, zip}), skirt (*attribute:* fastener {button, zip}), pullover, shirt (*attribute:* fastener {button}), sweatshirt, nightgown, jacket (*attribute:* fastener {button, zip}) , coat (*attribute:* fastener {button, zip}), cardigan (*attribute:* fastener {button})
Footwear	shoes (*attribute:* side {left, right}), sandals (*attribute:* side {left, right}), boots (*attribute:* side {left, right}), trainers (*attribute:* side {left, right}), slippers (*attribute:* side {left, right})
Accessories	scarf, gloves (*attribute:* side {left, right}), cap, hat, beret, socks, tights (*attribute:* side {left, right}), umbrella
Body	up, down, foot (*attribute:* side {left, right}), arm (*attribute:* side {left, right}), leg (*attribute:* side {left, right}), hand (*attribute:* side {left, right}), neck, waist, head
Actions	dress, undress, wear, take, take off, remove from, zip, unzip, tie up, put on, button up, unbutton

Table 4.1: Conceptual model of *iTutorials*

4.1.2 The concept of *tutorial*

A tutorial is the entity on which our system is based. The concept is modelled as a set of simple sequential actions on how to complete a task adapted to the user's habits and preferences. Each of these on-screen instructions constitute a step. Steps may be of two different types: (1) a *guideline*, which comprises a textual instruction, an audio track and a video footage; (2) a *question*, which comprises a textual query, an audio track and a single picture. In both cases, textual phrases contain a set of keywords that provide the meaning of the step. Figure 4.1 depicts the scheme of a tutorial as just explained.

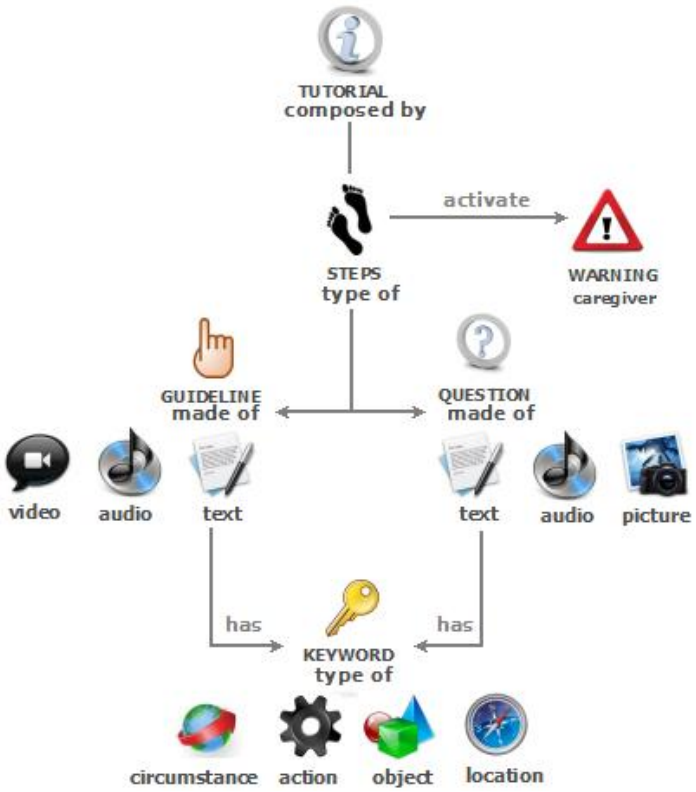

Figure 4.1: Scheme of a tutorial

Keywords can be type of *circumstance (cc)*, referring to a fact or an event, *action (act)*, normally a verb, *object (obj)*, referring to a visible and tangible entity, or *location (loc)*. Some examples of textual analysis are presented next.

- QUESTION: Are you sure you want to cancel*(act)* the tutorial*(obj)*?
- QUESTION: Do you fancy to add*(act)* sugar*(obj)*?
- GUIDELINE: Pour*(act)* milk*(obj)* from the vacuum bottle*(obj)* to the mug*(obj)*.
- GUIDELINE: It is rainy*(cc)*. Take*(act)* your umbrella*(obj)*.

Considering the *conceptual model* we previously defined and the structure that textual instructions commonly present, it is possible to establish a process of automatic step generation based on Natural Language Processing (NLP) and behavioural agents (Allen et al., 2001). The process involves the implementation of an inference engine to generate the basic instructions (guidelines and questions) for a user to complete an activity. The inference engine would use a lexicon of terms (extracted from the conceptual model), a regular grammar, and algorithms of syntaxes to generate syntactically correct sentences. Since our present work already addresses other issues of relevance, this approach is set aside for future work.

4.1.3 Activity Diagrams

Considering the *iTutorials* domain, we have designed the activity diagram for each of the ADLs described in section 3.3. These diagrams represent the relations that are established among concepts and actions regarding the *conceptual model* previously defined.

Since daily routines can be performed differently depending on the user's habits and preferences, *iTutorials* must be able to adapt its content to the user context. Thus, it is needed to ensure that the various work-flows that might compose a tutorial are consistent by means of integrity restrictions. Table 4.2 describes the different types of restrictions that might be imposed to the activity diagrams to assure their correctness.

Expression	**Meaning of the integrity restriction**
optional(obj)	it is up to the user to use object obj
optional(act, obj)	it is up to the user to execute the action act upon object obj
after(act, obj_1, obj_2)	the action act is executed upon object obj_1 after executed upon object obj_2
after(act_1, act_2)	the action act_1 is executed after the action act_2 is completed
OR(obj_1, obj_2, obj_3)	the set of $objects$ are exclusive
type of(obj_1, obj_2)	object obj_1 is a subtype of object obj_2
condition(obj_1, obj_2)	object obj_1 has an instance only if object obj_2 also has
on top of(obj_1, obj_2)	object obj_1 is placed over object obj_2

Table 4.2: Type of restrictions for the activity diagrams

This set of restrictions is used to determine the sequence in which objects are used and actions executed regarding the mental model of the user, and also to define semantic relations among the concepts involved. Diagrams in figures 4.2, 4.3 and 4.4 illustrates the conceptual relations and restrictions for the activities *Preparing a sandwich*, *Preparing a coffee* and *Dressing to go out* respectively. Please refer to the appendix on section B.1 for the diagrams of the two other *Dressing* activities.

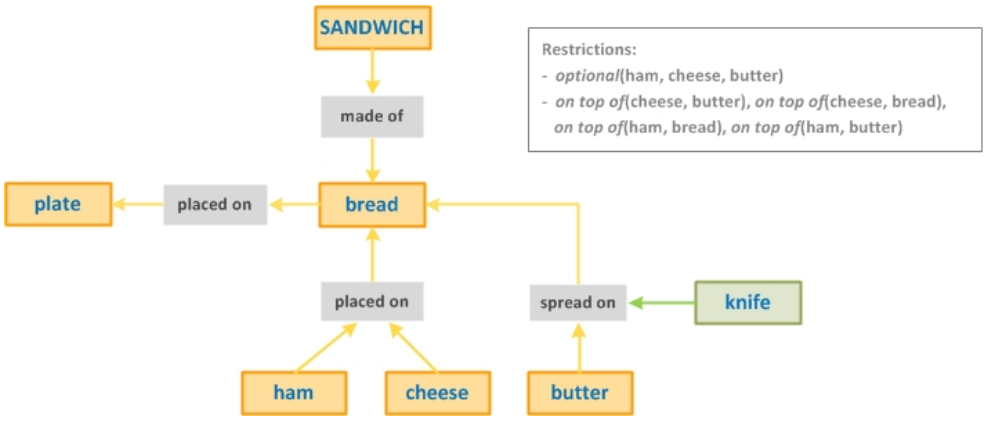

Figure 4.2: Activity diagram for the *Preparing a sandwich* tutorial

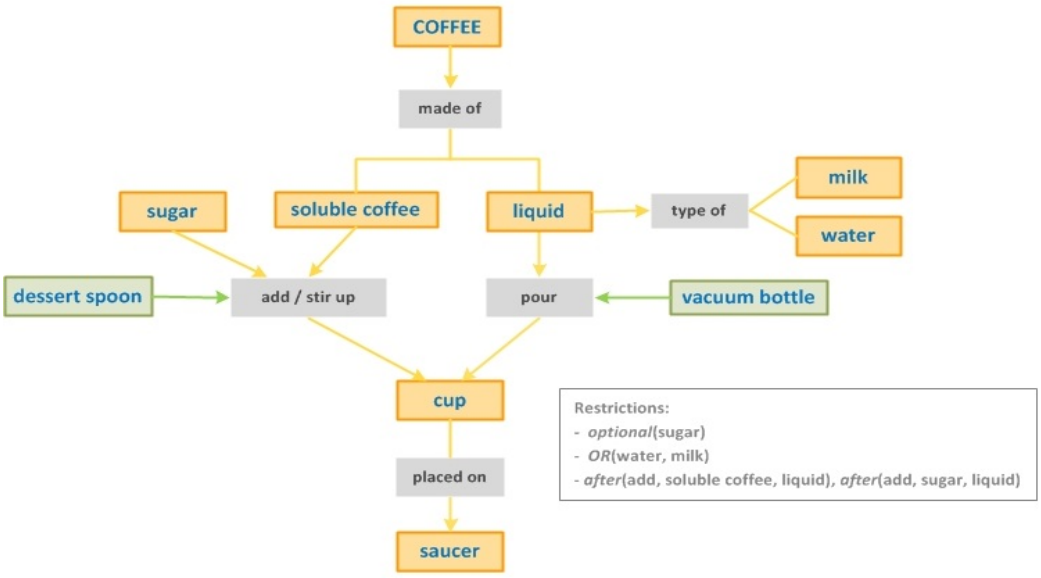

Figure 4.3: Activity diagram for the *Preparing a coffee* tutorial

There are a set of general restrictions that commonly apply to the three *Dressing* activities: *after*(undress, down, up), *after*(put on, arm, neck), *after*(put on, waist, leg), *after*(remove from, arm, neck), *after*(remove from, leg, waist), *after*(remove from, unzip), *after*(remove from, unbutton), *after*(zip, put on), *after*(button up, put on), *after*(dress, undress). Three-tuple restrictions specifies the logic order in which body parts are involved for getting dressed so that the task is successfully completed, whereas two-tuple restrictions describes the priority of one action upon another. Diagrams on figures 4.4, B.1 and B.2 take into account these restrictions.

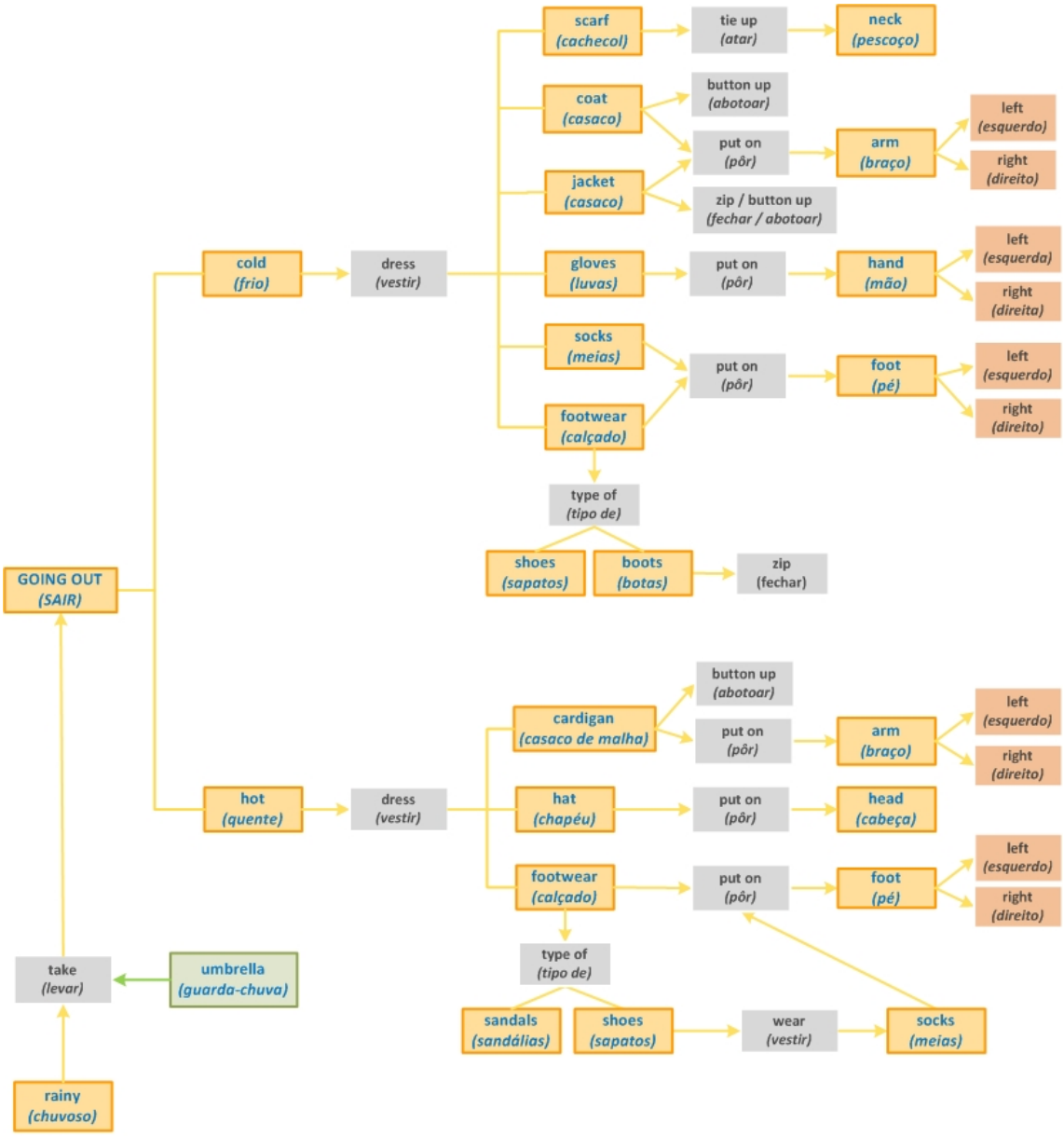

Figure 4.4: Activity diagram for the *Dressing to go out* tutorial

4.2 Activity Work-flows

The activity diagrams previously presented not only let to acknowledge the interactions among the different concepts but also picture the alternative work-flows composing an activity. At this point, it was considered convenient to focus on three of the ADLs for the design of our system: *Preparing a sandwich*, *Preparing a coffee* and *Dressing to go out*. This decision was made for two important reasons:

1. **Ethical issues.** The other two activities, *Dressing to exercise* and *Putting the pyjamas on*, necessarily require that users get naked or change their underwear. These situations might compromise their performance, since these actions could be considered a severe intrusion of intimacy by the elderly.

2. **Proof of concept.** In order to be able to accurately test *iTutorials*, it is preferable to firstly run a *proof of concept* with few tasks from each category. By focusing on a small group of tutorials we manage to assess at close range not only their functional and technical performance but also the usability of the user interface.

Activity name:	Name assigned to identify the activity.
Description:	Definition of what the activity is about.
Activation for display:	Events that trigger the activity.
Items needed:	Material needed for the proper performance of the activity.
Preconditions:	Description of what needs to be arranged before the task starts.
Stepwise activity:	Specification of the step-by-step actions composing the activity. There are two types of steps: questions (Q) and guidelines (G).
Extensions:	Alternative flow of steps for the activity work-flow.
Contraindications:	Descriptions of those affections which might prevent the user from performing the activity or using certain items.

Table 4.3: Structure followed to describe the activity work-flows

Table 4.3 describes the structure used to describe the activity work-flows accounting their preconditions, items involved, trigger for display, sequence of steps, alternatives flows and contraindications. First instruction of a tutorial is always intended to familiarize the user with the items involved for recognition. In case any of the items is missing, the caregiver is promptly informed.

4.2.1 Preparing a sandwich

This tutorial consists of preparing a sandwich that contains any of these ingredients: butter, ham, cheese. The user is asked whether or not s/he likes to add each of the ingredients to the sandwich as long as they are allowed to be part of his/her diet. Soft bread is recommended to be used for the sandwich so

that chewing is easier for elders. Please refer to section B.2.1 for the translation of this activity work-flow into Portuguese.

Activity name:	PREPARING A SANDWICH
Description:	It consists of preparing a sandwich made of ham and cheese without having to cook.
Activation:	The tutorial is offered when the activity is requested by the user or scheduled by his/her caregiver.
Items needed:	2 slices of bread, some slices of ham, some slices of cheese, butter, a knife, a plate.
Preconditions:	1. All the items must be arranged at the kitchen. 2. The loafs of bread must be already placed on the plate.
Stepwise activity:	
G1. NECESSARY ITEMS. Make sure all these items are in the kitchen counter: 2 slices of bread, ham, cheese, butter, a plate, a knife. (G1, yes) Q1. Would you like butter on your sandwich? (Q1, yes) G2. SPREAD BUTTER. Spread a thin layer of butter on the two slices of bread using the knife. Q2. Would you like some cheese on your sandwich? (Q2, yes) G3. PLACE CHEESE. Place some slices of cheese on your bread. Q3. Would you like some ham on your sandwich? (Q3, yes) G4. PLACE HAM. Place some slices of ham on your bread. G5. PUT THE SANDWICH TOGETHER. Put together the two slices of bread to make a sandwich.	
Extensions:	(G1, no) ACTION: Send warning to caregiver.
Contraindications:	It is not indicated for those users suffering from: 1. Low vision for safety reason (*e.g.* a user unable to see knives clearly) 2. Moderate tremors 3. Hemiparesis affecting strength and sensibility on hands and fingers 4. Dysphagia Do not use butter if the user has high cholesterol.

Table 4.4: Activity work-flow for the *Preparing a sandwich* tutorial

4.2.2 Preparing a coffee

This tutorial consists of preparing a coffee without having to heat liquids or use the coffee maker. In addition to instant coffee, milk or water can be indistinctly used to prepare the beverage. In both cases, a vacuum bottle is arranged to keep the liquid warm. Please refer to section B.2.2 for the translation of this activity work-flow into Portuguese.

Activity name:	PREPARING A COFFEE
Description:	It consists of preparing a coffee without having to use the coffee maker.
Activation:	The tutorial is offered when the activity is requested by the user or scheduled by his/her caregiver.
Items needed:	Soluble coffee, milk or water on a vacuum bottle, sugar, a spoon, a mug.
Preconditions:	1. All the items must be arranged at the kitchen. 2. The vacuum bottle should contain either milk or water (according to user preferences) already heated.
Stepwise activity:	
G1. NECESSARY ITEMS. Make sure all these items are in the kitchen counter: a mug, a vacuum bottle, sugar, soluble coffee, a spoon. (G1, yes) G2. POUR MILK. Pour milk from the vacuum bottle to the mug. G3. ADD SOLUBLE COFFEE. Add 2 spoons of soluble coffee to the mug. Q1. Would you like some sugar with your coffee? (Q1, yes) G4. ADD SUGAR. Add a spoon of sugar to the mug. G5. STIR UP COFFEE. Use the spoon to stir your coffee up.	
Extensions:	(G1, no) ACTION: Send warning to caregiver. *(if water)* G2. POUR WATER. Pour water from the vacuum bottle to the mug.
Contraindications:	It is not indicated for those users suffering from: 1. Essential tremors 2. Hemiparesis affecting strength and sensibility on hands and fingers Do not use milk if the user has liver problems. Do not use sugar if the user suffers from diabetes.

Table 4.5: Activity work-flow for the *Preparing a coffee* tutorial

4.2.3 Dressing to go out

This tutorial consists of putting on outerwear in order to be ready to go outdoors. Clothing that are offered for the user to wear along the tutorial performance depends on different factors:

1. **The caregiver choice.** When the activity is scheduled, the caregiver is responsible for reporting the exact clothes to be used along the tutorial performance, selecting among different options. For instance, the caregiver will choose whether the user wears a jacket or a coat, and the type of closures it has (zip or buttons).

2. **The temperature.** It is a variable of weight in such a routine as dressing to go outdoors, since the temperature can range from frosty to very hot depending on the time of the year. The following schema shows the weather categorization according to the temperature in degree Celsius.

- if temperature $\leq$ 10 °C then it is *cold*
- if 10°C $<$ temperature $\leq$ 18°C then it is *chilly*
- if 18°C $<$ temperature $\leq$ 24°C then it is *warm*
- if temperature $>$ 24°C then it is *hot*

These categories are later used to discriminate the different flows of interaction and the extensions patterned for the activity.

3. **The current clothing.** One of the alternatives for monitoring the user during the execution of the tutorial is asking about those clothes s/he is supposed to be already wearing, such as the house slippers. Thus the user gets focused on the performance by becoming aware of what s/he is wearing, and acts according to the instructions to complete the task.

4. **The user preferences.** Although the caregiver might choose the items to be used during the tutorial, the user is who eventually decides whether to wear certain clothes or not depending on his/her mood and taste. For instance, a user might not feel like wearing gloves despite the cold weather but might like the idea of button her coat on. By allowing the user to make such decisions, the application might contribute to enhance the user's sense of self-dependence to some extent.

Interviews conducted with experts (caregivers and doctors) allowed to know more about the most common outerwear of the Portuguese elders as well as other cultural habits that might condition this activity. The information gathered was used to make certain design decisions listed below:

- Portuguese language uses the general term *casaco* to refer to either a coat or a cardigan. Since a jacket is an item of clothing that few elderly may use, the Portuguese translation of this activity in section B.2.3 arbitrarily uses the term *casaco* with no distinction for jacket, coat or cardigan.
- Outwear such as jackets and coats are necessarily fastened when the temperature is *cold*. Otherwise, the option is only suggested to the user.
- Wearing gloves is up to the user in *chilly* and *cold* days, since some elders have limited mobility in their hands when wearing this item.
- On *hot* days, the user is asked if s/he would like to wear a hat. This is an important detail especially for men, since many have the habit of wearing a beret.

In order to facilitate the reading of this document, and since this activity work-flow is very extensive, please refer to appendix B.2.3 for a complete specification in Portuguese (use the activity diagram 4.4 for the English translation of the terms involved).

4.3 User Profiling

Any supportive system aimed at impaired older adults must accommodate the current capabilities and limitations presented by individuals, which might worsen over time. One of the key features that *iTutorials* addresses is the *personalization* of tutorials according to:

1. Those **conditions caused by dementia or stroke** (*e.g. hemiparesis* or *visual agnosia*) which might prevent the user from successfully completing a tutorial. In this case, our supportive system compares the user profile provided by caregivers/doctors to a list of reference recommendations based on medical criteria in order to determine whether or not a tutorial is adequate for the user. Please refer to section 6.3 for the description on how the user interface accommodates these conditions.

2. Those **metabolic disorders and chronic conditions** (*e.g. diabetes* or *high cholesterol*) which might prevent the user from performing some step of a tutorial. In this case, our system patterns the tutorial by dismissing such a step and adjusting the rest of steps properly.

The process of user profiling considered not only the types of disability affecting our target users as described in section 3.1, but also the contraindications for each of the activities supported by *iTutorials*. Therefore, many functional and physical conditions were evaluated, some of them being dismissed for either being out of the scope of our proof of concept (*e.g. motor aphasia*) or for being too complex (*e.g. hemiplegia*). After several iterative evaluations, which progressively refined the user profile, a model based on nine descriptors was obtained: *apraxia, osteoporosis, tremors, hemiparesis, dysphagia, visual agnosia, diabetes, hypertension, hypercholesterolemia*. These set of attributes is diverse and descriptive enough to divide our target population into different groups of users sharing similarities. The user profile also collects information about personal details of the user such as the name, the surname, and the gender.

Generally, each of the descriptors composing the user profile is quantified using a 3-level scale: 0 - none, 1 - mild degree, 2 - moderate degree. Users suffering from a severe degree of impairment were not considered to be part of the target population due to their worsening in basic human functions. Some of the conditions (*diabetes, hypertension, hypercholesterolemia*) are assessed separately using binary quantifiers: 0 - negative (user not affected), 1 - positive (user affected).

Table 4.6 summarizes the evaluators used for each medical descriptor and the restrictions they apply to tutorials. Each of the cells in column *Not Recommended* refers to those tutorials not suitable for a user to perform in case s/he is affected by the corresponding condition (column *Descriptor*) with the corresponding acuteness (column *Evaluator*). These restrictions, that were assessed by doctors and caregivers, are later used to personalize the display of *iTutorials* according to the user profile each individual presents.

Descriptor	Impaired function	Evaluator	*Not* Recommended
Apraxia	Mobility	Mild	Dressing Go out
		Moderate	Preparing Food[1], Dressing Go out
Tremors	Motor coordination	Mild	*(no filtering)*
		Moderate	Preparing Coffee
Hemiparesis	Mobility	Mild	Preparing Coffee, Dressing Go out
		Moderate	Preparing Food, Dressing Go out
Osteoporosis	Mobility	Mild	*(no filtering)*
		Moderate	Dressing Go out
Visual Agnosia	Recognition	Mild	*(no filtering)*
		Moderate	Preparing Food, Dressing Go out
Dysphagia	Swallowing	Mild	*(no filtering)*
		Moderate	Preparing Sandwich
Diabetes	Insulin production	Positive	Preparing Coffee: no sugar
Hypertension	Blood pressure	Positive	Preparing Sandwich[2]
High cholesterol	Circulatory system	Positive	Preparing Sandwich: no butter

Table 4.6: Restrictions that each profile descriptor applies to *iTutorials*

To establish the restrictions we considered those abilities that users bring into play when executing a tutorial. Among those abilities we had: to button up a jacket or tie your shoes, to put on a cardigan, to pour hot liquids into a mug, to spread butter with a knife, *etc.* None of them can be taken for granted as effortless, when in fact may compromise the performance of the elders due to the amount of cognitive activity they engage.

4.4 Contextualization

To acknowledge the elders' habits (*e.g.* a user does usually wear sandals) and circumstances (*e.g.* it is a very hot day) conditioning the performance of daily routines becomes a key factor for improving interaction with end-users.

Caregivers are responsible for selecting the items to be used along a certain tutorial according to the user's habits and limitations (*e.g.* the user cannot drink milk due to liver problems). Thereby, the suitable interaction flow for activity guidance can be patterned more effectively. Some decisions that caregivers make upon the context are:

- to include ingredients to a tutorial, such as *butter* to make a sandwich or *sugar* to prepare a coffee
- to choose between *water* or *milk* to prepare a coffee

[1]Refers to both *Preparing a sandwich* and *Preparing a coffee* tutorials
[2]Refers to a salty sandwich

- to include items of clothing to a tutorial, such as *socks*, a *hat* or a *scarf*
- to select the type of footwear to use *(boots, shoes, sandals)* for going out
- to specify the type of fastener *(buttons, zip)* that the cardigan or the coat to wear has

Information on time and weather is provided by web services for environmental contextualization. Such type of data is of real importance for the *Dressing to go out* tutorial in order to categorize the current weather (cold, chilly, warm, hot). Acknowledging the temperature and humidity outdoors as well as the user's gender from the user profile, the clothes to put on along the tutorial are accurately selected (*e.g.* if the elder is a woman, she should be offered to wear a hat instead of a beret). If the weather forecast announces showers, the user is warned to take the umbrella.

4.5 Heuristic Evaluation

Before prototyping our system, it is necessary to evaluate the previous user interface in order to identify usable elements to keep or emphasize, and also to detect usability problems and other contextual hindrances to correct when designing and prototyping a better version.

Nielsen's heuristics	**Questions addressed in the evaluation**
H1. Visibility of system status	Are users kept informed about what is going on? Is suitable feedback provided within reasonable time about a user's action?
H2. Match between system and the real world	Is the language used at the user interface simple?
H3. User control and freedom	Are there ways of permitting users to easily escape from places they unexpectedly find themselves in?
H4. Consistency and standards	Are the ways of performing related actions consistent?
H5. Help users recognize, diagnose and recover from errors	Are error messages helpful? Do they use plain language to explain the nature of the problem and propose a solution?
H6. Error prevention	Is it easy to avoid errors? If so, where and why?
H7. Recognition rather than recall	Are objects, actions and options always visible?
H8. Flexibility and efficiency of use	Have accelerators been presented in order to permit more experienced users to carry out tasks more quickly?
H9. Aesthetic and minimalist design	Is the information provided useful and appropriate?
H10. Help and documentation	Is help information provided that can be simple searched and simply followed?

Table 4.7: Heuristics questions used for the assessment of usability problems

Heuristics evaluation examines and judge the user interface for usability issues. In this technique, a set of usability heuristics, the **Nielsen's usability heuristics** (Nielsen, 1994), are individually applied

to *iTutorials* in order to identify problems and assess their severity by using the following scale: 1 - cosmetic problem; 2 - minor problem; 3 - important usability problem, correction needed; 4 - usability catastrophe, imperative correction. Table 4.7 shows the questions that each of these heuristics addresses when assessing a system to detect usability problems. The list of usability heuristics that the previous user interface broke are reported next.

H1. Visibility of system status	**H2. Match between system and the real world**
Description: It is necessary to inform the users where they are, where they come from and where they can go	*Description:* It is needed to use terminology that is familiar to the user, not technical words such as STOP or SOS
Correction: Include a reference to the previous and following step	*Correction:* Substitute all the fuzzy words for others that are more familiar to our target users
Severity: 3 - Correction needed	*Severity:* 3 - Correction needed

H3. User control and freedom	**H6. Recognition rather than recall**
Description: Avoid forcing the user to follow inflexible paths (*e.g.* a blank screen appears when the tutorial is finished)	*Description:* Names used to designate actions are poorly descriptive and too generalist
Correction: Add visible buttons to cancel any step of the tutorial, and exit the execution at any time	*Correction:* Add icons to the buttons in the tutorials to turn pictures easy to associate with actions (*e.g. cooking lunch*)
Severity: 3 - Correction needed	*Severity:* 3 - Correction needed

Table 4.8: Heuristic violation H1, H2, H3 and H6 on the previous user interface

Figure 4.5: Violation of heuristics H1 and H2 when executing *iTutorials*

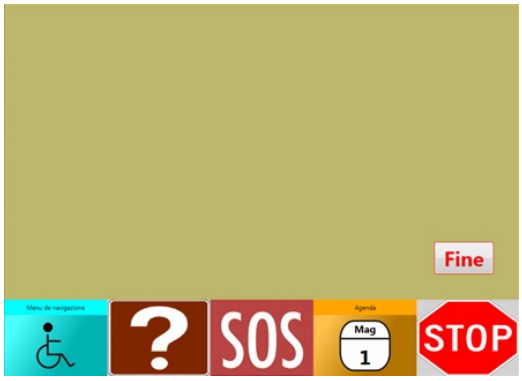

Figure 4.6: Violation of heuristic H3 at the end of any tutorial execution

H5. Error prevention	**H8. Aesthetic and minimalist design**
Description: The common conventions regarding colors are not followed	*Description:* Text used in question messages is smaller than text used in answering buttons
Correction: Use red color to indicate negation and green color to indicate affirmation	*Correction:* Balance the text size in the same screen for a more aesthetic view
Severity: 3 - Correction needed	*Severity:* 2 - Minor problem

H9. Help users recognize, diagnose, and recover from errors	**H10. Provide help and documentation**
Description: Errors are not reported to the user on-screen	*Description:* There is no button to request help whenever the user is executing any step
Correction: Explain the nature of the error to the user and constructively suggest a solution in order to move on	*Correction:* Add a help button visible at any step of the tutorials
Severity: 3 - Correction needed	*Severity:* 2 - Minor problem

Table 4.9: Heuristic violation H5, H8, H9 and H10 on the previous user interface

Figure 4.7: Violation of heuristic H6 when listing the existing categories of tutorials

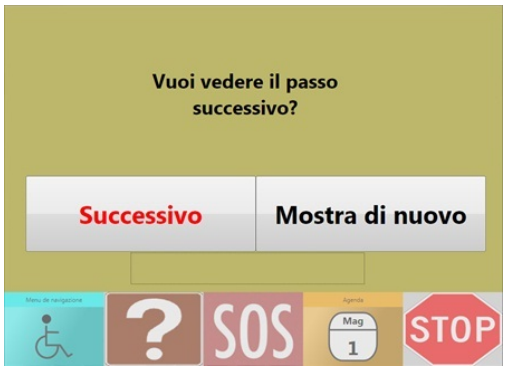

Figure 4.8: Violation of heuristic H8 when displaying an interrogation message

5 Prototyping

Prototypes are excellent means of exploring user interfaces without straying from the big picture by focusing too much in details. The following sections addressed different ways of modelling the user interface by picturing significant relationships between major user interface elements.

5.1 Storyboards

Storyboards are typically used for two purposes. On the one hand, they develop an interface-flow that reflects the behavioural view of a single use case (*e.g. Preparing a coffee*), and on the other hand, they enable to gain a high-level overview of the user interface, and thereby ask fundamental usability questions (Truong et al., 2006).

Along this section we illustrate the interaction flows for the *Preparing a sandwich* activity. A first draft was pictured resembling the design of the previous interface, but taking into account the outcomes of its heuristic evaluation and most importantly, the aging human factors described in section 2.3. This initial approach to the interface design modelled an structure based on three horizontal stripes with different purposes:

- a *top bar* to inform about the system status,
- a *central space* to display the supporting elements that feature *iTutorials*,
- a *bottom option menu* to perform actions and help users recover from errors.

This structure remained the same along the prototyping, but its content was transformed to improve usability. Regarding the functional behaviour of the design, it is required that either the user or the caregiver selects a tutorial among those available in order to start up. When any of the tutorial is completed, end-users are congratulated for the effort, so that their self-confidence is strengthened.

The following list enumerates the most significant changes applied to the first draft in order to obtain the final sketch of the storyboards. The first and second version were reviewed by actual caregivers, who do have the most experience in interacting with our target users, while the final was used to be tested with end-users as a low-fidelity prototype. Please refer to annex E for the complete storyboards.

1. **Redesigning the bottom option menu.** This option menu initially included buttons for returning to the main menu (option TUTORIAIS), alerting the caregiver (option COMUNICAR) and requesting for help (option AJUDA). The three options turned out to be underused, especially since users already had a way to contact their caregiver by means of another assistive device. Hence, the help option was moved into the top bar aligned to the right to turn it more visible, while the tutorials option was removed to be substituted by a more recognizable option (button CANCELAR) that led to the same place, the home page. Figure 5.1 illustrates these adjustments from the first draft (left picture) to the final draft (right picture).

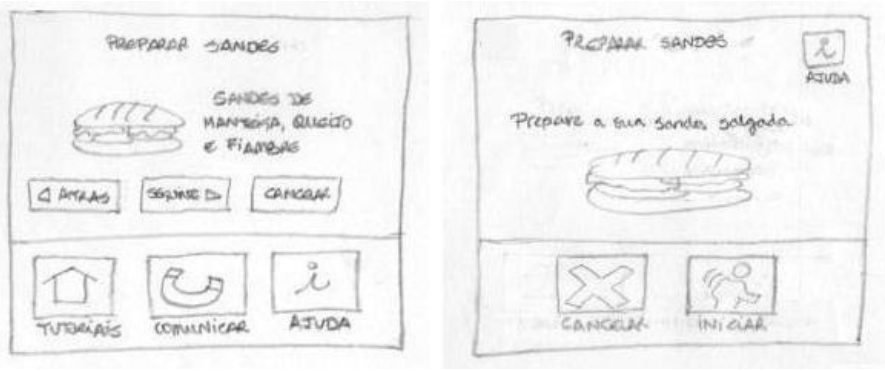

Figure 5.1: Storyboards. Transformation of the bottom option menu

2. **Improving efficiency of use.** In order to ease the interaction for elders and make the response alternatives more visible in each of the steps, options such as ATRÁS, SEGUINTE, SIM, NÃO and CANCELAR, initially placed in the central space below the textual instruction, were moved into the bottom option menu. Figure 5.2 illustrates these relocations from the first draft (left picture) to the final draft (right picture).

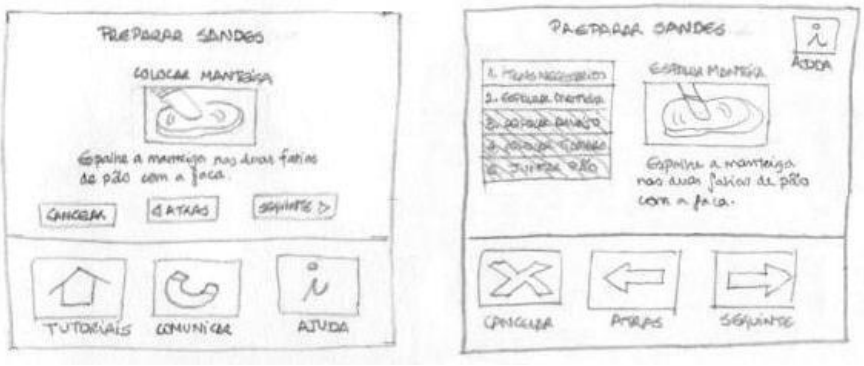

Figure 5.2: Storyboards. Addition of a navigation table and relocation of the function buttons

3. **Acknowledging which step is reached.** A navigation table containing all the steps of the tutorial is added to the central space, aligned to the left. Those steps that the user has already completed are available to click on, whereas those steps to be completed appeared unavailable. Thus, the user acknowledges the point of performance s/he is at, and how many steps are left to finish the tutorial. Additionally, the user can go back to any step already performed. Figure 5.2 illustrates how the interface changed when the navigation table was added to the final draft (right picture).

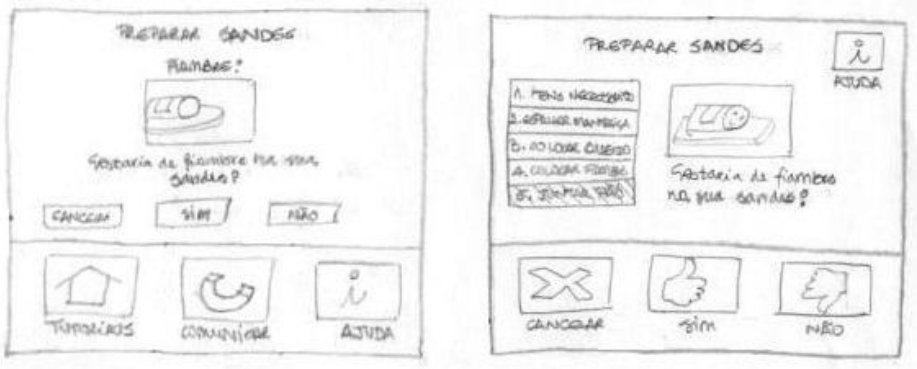

Figure 5.3: Storyboards. New icons for the function buttons SIM, NÃO, and CANCELAR

4. **Recognition rather than recall.** The SIM and NÃO buttons were enlarged to resemble an affirmative or negative answer by using thumbs up and thumbs down. Furthermore, the icons were coloured green and red respectively to emphasize the idea of acceptance or rejection. The same mechanism was applied to the CANCELAR button, which incorporates a white cross on a red background, and the ATRÁS, SEGUINTE, VOLTAR and ACABAR buttons, which picture the corresponding actions by using arrows. Figure 5.3 illustrates how the interface changed when the new icons were added to the final draft (right picture).

5.2 Interaction Scenarios

The following scenario narrates a successful interaction session that an end-user might perform with the resulting interface when following the tutorial for *Preparing a sandwich*.

5.2.1 Scenario 1: Claudia fancies a sandwich

It is Saturday evening and Claudia is asked by her caregiver if she fancies a sandwich. She is starting to feel hungry, so she moves into the kitchen near to the counter where all the items are already gathered for her to perform the tutorial. Since Claudia suffers from high cholesterol, she will not be asked to add butter to her sandwich.

Claudia clicks on the <TUTORIAIS> button to start the application, pressing the <PREPARAR REFEIÇÃO> button and then the <SANDES> button. Claudia is sure she fancies a sandwich so she clicks on the <INICIAR> button to launch the tutorial. She is firstly asked to make sure any of the items is missing, so she checks them one by one on the kitchen counter. Since all the items are gathered, Claudia clicks <SIM> to continue. Claudia is then asked if she would like to add cheese to her sandwich, so she clicks <SIM> and perform according to the instruction. She moves to the next step by pressing <SEGUINTE>. Claudia is then asked if she would like to add ham to her sandwich, but she prefers not to, so she clicks on the <NÃO> button. Claudia is now at the last instruction where she puts together the two slices of bread to get the sandwich ready. She then clicks on the <SEGUINTE> button to arrive at the end of the tutorial, where she is congratulated for her performance. Finally, she presses <ACABAR> in order to end the tutorial and go back to the home page.

5.3 Low-Fidelity Prototype

These kind of paper prototypes are used to simulate any interaction flow, allowing to change not only the look & feel of the interface but also any sequence of design with almost no cost, since no code lines or bugs need to be corrected at that phase (Landay & Myers, 2001). Plus, these prototypes can usually simulate a real device by using only few materials. Our low-fidelity prototype was basically made of cardboard and glue. Figure 5.4 shows two pictures of how our prototype looked like.

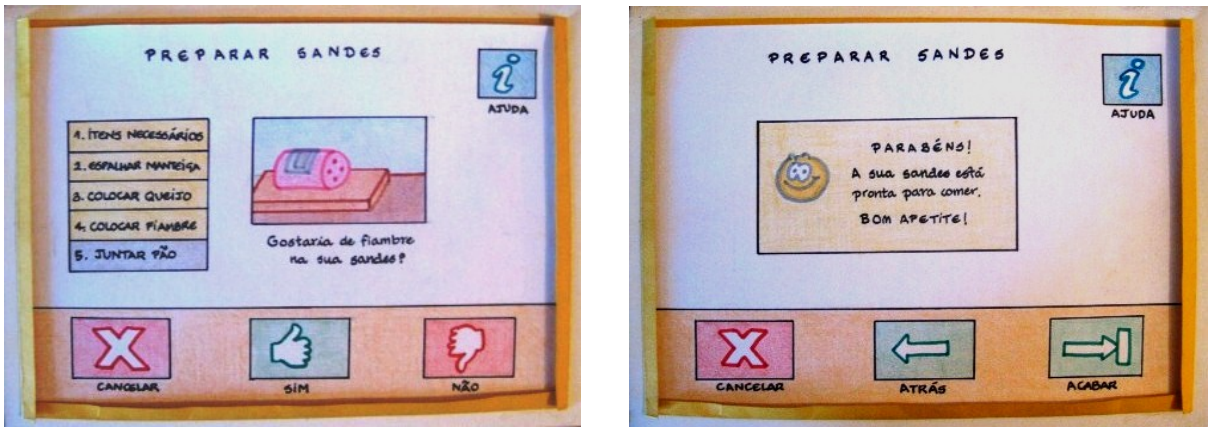

Figure 5.4: Pictures of the low-fidelity prototype for the *Preparing a sandwich* activity

Before testing the usability of such a prototype, it was required to perform two important steps in order to guarantee the success of this user-centered evaluation:

- *Choose potential evaluators.* We selected two end-users in their seventies (a married couple) who lived with his son and daughter-in-law. Both elders are suffering from a *mild Alzheimer*: the woman

was affected by a motor coordination impairment *(apraxia)*, especially when getting dressed; her husband was affected by prominent memory problems (*e.g.* going to the supermarket twice since he could not recall that he had already bought a carton of milk). Before the real evaluation, users were exposed to the prototype in order to get familiarized with the device and the interaction process. They both seemed excited and eager to participate.

- *Prepare the usage scenarios.* The prototype was based on the *Preparing a sandwich* activity, simulating the main work-flow as described in section 4.2.1 and also pictured in the final draft of the storyboards. Both users were asked to execute the activity through the same interaction session in order to compare and contrast their performance.

The testing of the low-fidelity prototype was helpful to have an idea about how usable the design of the prototype was. For being the first time users encountered the design, they performed with little support along all the task scenario. Their impression of the layout was positive, understanding the instructions and reacting within short-time through the buttons on the down menu. However, they got confused by trying to match the guidelines with reality, looking for the items needed at the steps. Options were clear and recognizable and did not lead to error-prone conditions. Users made no comment on the design except for the size of the font, which should be larger (they both actually needed reading glasses) and better accompanied by audio. Since no relevant usability issues were found, it was decided to use this model for the implementation of the user interface.

6 Implementation

The final architecture of *iTutorials* is mainly composed by a conjunction of two different modules: the intelligent agent and the user interface. These elements get communicated through Distributed and Layered Architecture (DLA) connections using data packages. The solution was envisioned using such an architecture so the intelligent agent, that launches an interface for the caregiver to manage data, can be executed in a machine (*e.g.* a device such a PDA) while the user interface can run in a touch-based notebook. The following sections describe how these modules have been developed and interconnected.

6.1 Agent Architecture

One of the software components of the *SHARE-it* project was the MAS, whose agents interacted and collaborated among themselves as autonomous software entities in order to solve problems (Russell & Norvig, 2010). This version of *iTutorials* is focused on adapting the behaviour of one of these intelligent agents, the **User Agent**, which is in charge of all the functions related to our main concepts: end-users and ADLs.

JADEX[1], an agent-oriented reasoning engine for writing rational agents with XML and the Java language, was used for programming the User Agent under the **Belief-Desire-Intention (BDI) model**. This model eludes to the mental attitudes that generate human action to prescribe the behaviour of software agents. This behaviour is defined by a set of *Beliefs* representing their informational state, and a set of *Goals* that can be accomplished by executing *Plans*. The three main goals that the User Agent is determined to accomplish are: (1) acquiring the user profile and his/her personal data, (2) selecting the suitable tutorials for the user to perform among those available, (3) adjusting the steps of the tutorials according to the user needs and the particular context.

6.1.1 User Profile Plan

The first objective that the User Agent pursues is to acknowledge the current user profile. **Java Swing**, a Java widget tool-kit for designing applications with Graphical User Interfaces (GUI), was used for

[1] http://jadex.informatik.uni-hamburg.de

providing our agent with an interface. Thereby, the User Agent displays a window for the caregiver to introduce the user profile as defined in section 4.3, plus the personal data of the elder. Figure 6.1 depicts how the Swing widgets for the user profile window look like. When the button *Aceitar* is pressed, the corresponding facts related to the medical conditions of the user are updated in the *Belief Base* (a database of beliefs). Then, a new goal is created and dispatched in order to select the suitable list of tutorials for the user to perform. To reach this goal, a plan needs to be executed: `SelectTutorialsPlan`.

6.1.2 Selection of Tutorials Plan

Once our agent acknowledges the user profile, a set of rules are run in order to determine which tutorials are recommended to the user according to his/her medical condition and the cognitive and physical abilities each tutorial engages. This selection process entails comparing the values of the user profile to those descriptors meant to approve the recommendation of a tutorial regarding the restrictions defined in table 4.6. For example, an elder who is *diabetic* and suffers from a *mild apraxia* would not be able to perform the *Dressing to go out* tutorial, and any sugar intake would be suppress from the *Preparing a coffee* tutorial.

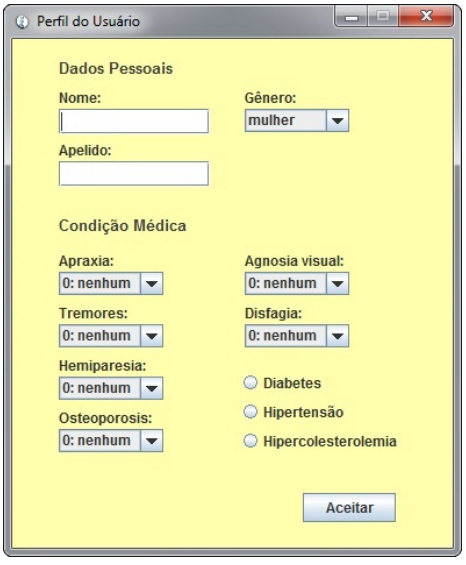

Figure 6.1: Caregiver GUI for introducing the user profile

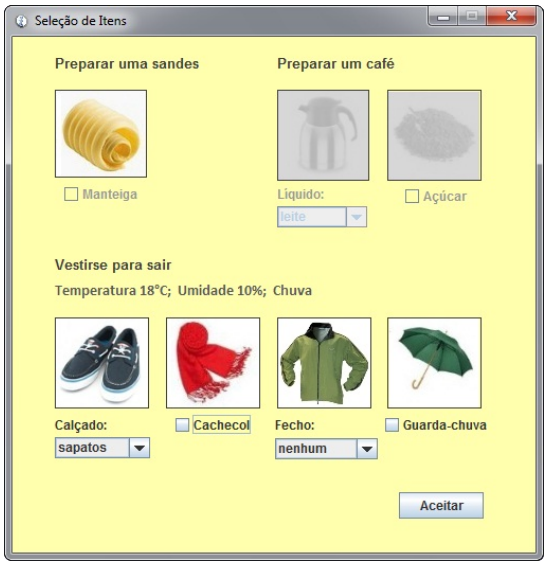

Figure 6.2: Caregiver GUI for selecting the items of each tutorial

The User Agent then displays another window as part of the **caregiver GUI**. This window allows the caregiver to select which items, among those displayed, are required for the user to successfully perform *iTutorials*. However, if one of the tutorials is actually not suitable for the user, its items are not enabled. Similarly, if any of the items within a tutorial is not recommended to the user, its selection

is neither enabled. Figure 6.2 depicts an example where the items for the *Preparing a coffee* tutorial not appear active, nor the check box for selecting the butter in the *Preparing a sandwich* tutorial.

The **Google Weather API** has been used to acquire the forecast information for a particular location within the next four days, including the current day. The request is sent to Google via an URL[2] that return an XML file with data on the current temperature, air humidity, wind speed and weather condition. This information (originally in English but translated into Portuguese by the User Agent) helps to decide which items should be initially displayed for the *Dressing to go out* tutorial depending on the current climate. When rainfalls are forecasted, an umbrella is added to the dressing items for selection. Figure 6.2 depicts how this window actually looks like when the temperature is 18°C and light showers are expected. When the button *Aceitar* is pressed, the facts corresponding to the selected items are updated in the Belief Base. Then, a new goal is created and dispatched in order to adjust the steps of the tutorials accordingly. To reach this goal, a plan needs to be executed: `AdaptTutorialsPlan`.

6.1.3 Adaptation of Tutorials Plan

Each of the tutorials selected are now customized step-by-step according to the personal context of the user. On the one hand, the tutorials related to the *Preparing food* category have been adjusted to the user's limitations. In particular, those ingredients that the caregiver considers not convenient for the elder are no longer used in any of the steps. On the other hand, the *Dressing to go out* tutorial has been adjusted to the user's habits and the outdoor environment. Hence, those items that the caregiver has selected because are common to the elder are used to pattern the work-flow of this tutorial, together with the personal data of the user and the weather forecast as specified in B.2.3.

The **ontology** (Rubio, 2010) created for the *SHARE-it* project was modified in order to render the new concept of *tutorial*. Each step is now identified as a guideline or a question, using different media for cueing the instruction given. This new representation later allows the GUI to adapt the interaction with end-users to their preferences through active debriefing.

6.2 DLA Communication

The DLA is normally used to develop cooperative systems distributed along several machines. Its mechanism of communication is based on a central element that manages the access and storage of the shared data from the other modules. In this case, when the User Agent wants to send some information to the GUI or vice versa, a DLA input/output connection is opened and a defined DLA package with the requested data is sent.

[2] http://www.google.com/ig/api?weather=city,state,country

6.2.1 DLA Package: User Profile

This DLA package is sent from the User Agent through DLA connection any time the user profile is introduced by the caregiver. The package (232 bytes) contain personal information about the user that the GUI needs in order to customize the display of *iTutorials*.

User Agent	DLA Server	GUI
(Caregiver GUI) Caregiver introduces the user profile		
(DLA Connection) Sends user profile to DLA Server		
	Stores the user profile (personal data, descriptors + quantifiers)	
		(DLA Connection) Retrieves user profile from DLA Server for customization

Table 6.1: DLA Schema for the user profile

6.2.2 DLA Package: List of Tutorials

Once the user profile is acknowledged by our application, the User Agent selects those tutorials recommended for the user to perform in-home. Each of the tutorials selected is later adjusted step-by-step to the personal context of the user, and sent from the User Agent to the GUI through DLA connection.

User Agent	DLA Server	GUI
Selects the list of tutorials according to the user profile		
(Caregiver GUI) Caregiver selects the items		
Adjusts the steps of the tutorials to the user context		
(DLA Connection) Send tutorials to DLA Server		
	Stores the tutorials (nameTut + numSteps(N) + nameCategory + N [type + title + text + media])	
		(DLA Connection) Retrieves the tutorials from DLA Server and displays

Table 6.2: DLA Schema for customizing the tutorials

The information contained in the corresponding DLA package is key data that results from the adaptation made by the User Agent according to the personal data and medical record of the user. This package is made of an array of tutorials, each of which contains the name of the tutorial (128 bytes), the name of its category (64 bytes), the number of steps (4 bytes), and an array of 1217 bytes for defining the content of each step (type of step, title, textual instruction, media).

6.3 User Interface

Different technologies were considered for implementing the user interface, from Adobe Flash to C#. However, as the User Agent was implemented using Java-based language, **Java Swing** as a GUI widget tool-kit seemed an appropriate option. Java applications can run similarly on any hardware or operating-system platform and are developed under a free software license, what supports the no-cost architecture devised for our portable solution. Java Swing also approaches assistive technologies with an Accessibility API.

In order to maintain the application scalable, each of the tutorials was coded on a different Java class, and a template was used for defining the common components (buttons, labels, icons, *etc*) of the GUI. Layout managers were used to determine the size and position of these components within a top-level container, generally a JFrame. The Java Media Framework (JMF) was used to enable audio and video to be added to our application, using JMStudio as a simple player GUI. However, JMF provides few up-to-date codecs and formats so that a free-available plug-in called FOBS was employed in order to play MP3 and AVI formats.

The accommodation of the user interface to those conditions considered by the user profile (*apraxia, osteoporosis, tremors, hemiparesis, dysphagia, visual agnosia*) is based on a simple design that favours interaction and avoids error-prone situations. Visual and auditory cues that complement textual instructions ease activity guidance for those users with sensory decline. Our touch-based interface prevents elders from having to learn how to use a mouse, which can be very tricky for those individuals with loss of upper extremity skills (*tremors, hemiparesis*). Elders affected by *visual agnosia* might benefit from labelling the items that any tutorial requires.

6.3.1 Conceptual Design

The storyboards presented in appendix C.2 were used as a model to implement the user interface and the interaction between the different screens. Aging human factors explained in section 2.3 were considered to adjust the interface (colouring, contrast, font size, *etc.*). However, several changes were applied to the prototyped design while coding:

- **Simplicity of design.** The interaction flow where the caregiver is warned after the user reports that any of the items is missing was reduced from three screens to only one. Instead of putting the user on hold, this new screen (figure 6.3) shows a message informing about the status of the tutorial and the actions triggered.

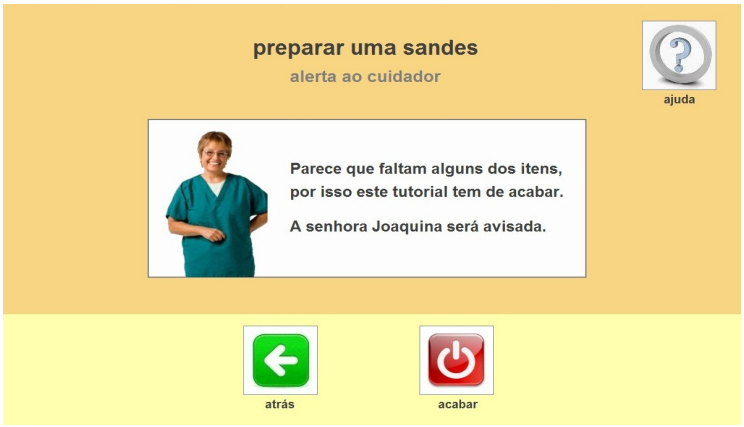

Figure 6.3: Snapshot of the new design for exiting a tutorial when any item is missing

- **Rearrangement of the layout.** It was considered pointless to maintain the name of the tutorial during all the steps as it provided no relevant information. Hence, the tutorial name centered at the top was removed and the gap was used to enlarge the size of the video (468 x 312 pixels). The space at the top of the navigation table was filled with an icon to illustrate which tutorial was the user performing plus the name of the current step, which appeared either if the step was a guideline or a question. Figure 6.4 illustrates the look & feel of the new layout.

Figure 6.4: Snapshot of the new layout for the interface

- **Auditory on-line help.** Initially, the on-line help was considered to be a new screen with an explanation about the purpose of the back page and the behaviour of each of its elements. However, it was considered hard for cognitively impaired elders to remember the information when going back. Therefore, the on-line help was embodied using audio tracks to make it more efficient to use.

6.3.2 Behavioural Design

Some new behaviours were added to the design of our interface apart from those intrinsics to the components (*e.g.* the thumb-down red button is used to say *no*) and those derived by the functionalities already explained in the prototyping (*e.g.* the navigation table).

- **Welcoming message on the home page.** The home page is based on a logotyped picture so that when the user clicks on, an audio track welcomes the elder and guides him/her on how to start the application. Figure 6.5 illustrates this particular behaviour of the home page.

Figure 6.5: Snapshot of the home page

- **Adding window decorations.** Our application window was decorated with a border and a title (*iTutorials 2011*), supporting button components that close or iconify the window at minimization.
- **Highlighting the current step.** To help the user knows where s/he is in the performance of the tutorial, the current step on the navigation table is highlighted with a thicker border. Figure 6.6 illustrates this change applied to the navigation table.
- **Simplifying the text.** The sentence that asked the user to check if all items were gathered nearby was changed from affirmative to interrogative, so that giving an answer (yes/no) became much more intuitive to the user. Figure 6.6 shows these textual arrangements.

Figure 6.6: Snapshot of the *Preparing a coffee* tutorial when checking the items

- **Introducing a beeper.** One of the Java Swing event handling is the beeper, which features a button that beeps when you click it. This event was added to all the interaction buttons so that the user becomes more aware of the action.
- **Playing a video footage again.** If the user wants to play a video again at a certain step, s/he can click right on its frame and it is automatically loaded again.
- **Stopping the on-line help.** The on-line help button is used to either play the audio track that explains the behaviour of the current elements on the screen, or to stop the audio track that is playing.

6.4 Media Recording

Video-clips used for illustrating each guideline of the tutorials were recorded along several days of August 2011 in Lisbon, Portugal. Portuguese was the language used for the interaction with the elderly volunteers who participated in the prototyping and experimentation phases. Therefore, visual and auditory cues were provided in this language. Activity work-flows as seen in section 4.2 were used to record the video footages.

The recording was assisted by a student from *Escola de Comunicacão Social* and a computer technician from *Instituto Superior Técnico*. A psychologist, Dra. Ana Ribas, also participated along the audio recording by reviewing the tone of the guidelines and providing a female voice to the audio tracks. The intervention of such experts was extremely valuable in order to decide about important issues: the best angle for filming, the proper order to introduce the items, *etc.*

7 Testing and Evaluation

7.1 Methodology

Along the development of *iTutorials* we employed a variety of evaluation methods for testing designs: from the Nielsen's heuristic evaluation to paper prototyping. Along this experimentation phase, we have used **empirical methods** by testing our system with real users through behavioural measurements (Dix et al., 2004). The ultimate goal of analysing these measurements is to find/create a prototype design that users like and use to successfully complete the given tasks. There were several points to address before conducting the user tests:

1. **Objective.** The main purpose of this phase was to evaluate the user interface for both learnability and usability, examining the performance and attitude of the elders while testing *iTutorials*. We also evaluated the functional behaviour and operability of the whole application.

2. **Location and duration.** Experiments were conducted at the elders' homes. Although one habitat differed from another, all end-users were evaluated under the same conditions. For convenience and efficiency reasons, none of the testing sessions exceed one hour.

3. **Equipment.** Observation techniques were used for evaluating end-users, so a camera for recording their performance and an alarm-clock for time controlling were required. All the items involved in the scenarios (*e.g.* cutlery, food or cookware) were provided to users. A notebook computer were all the hardware needed for running the application.

4. **Users.** Initially we had five volunteers for testing our application, but only three of them fitted the target population for *iTutorials*:

   - LOURDES S. Lourdes is a 71 years-old lady who lives in a flat with her dog. She is impaired in her *mobility* because of the amputation of both legs early in her infancy. She suffers from *senile dementia* still on a mild degree.

   - ALICE P. Alice is a 84 years-old lady who lives with his husband. She suffered a *stroke* last year and recovered pretty well. At the moment, she has some *weak tremors* in both hands and also suffers from *diabetes* and *obesity*, what restricts her intake of sugars and fats.

- FERNANDO P. Fernando is a 91 years-old elderly who lives alone. She suffers from a *moderate loss of memory* that impairs him in such a way that he requires day-care. He is also affected by *dysphagia*, having trouble to swallow certain kind of food.

On the testing day, all the arrangements were made before the experimentation begins, ensuring that the location (kitchen or bedroom) was conditioned, our application was ready to be run, and the material to be used during the tutorial simulation was available. This is assumed to be true in a real environment where users do live. Caregivers also complied with the preconditions of the tutorial chosen for the experiment, as described for each activity work-flow in section 4.2.

When elders arrived, they were told about the *purpose* and the *procedure* of the simulation (the system but not the user was evaluated in order to seek for improvements). They then were introduced to the interface and warned to firstly focus on understanding the instructions before proceeding to act consequently. Users were allowed to talk freely before the simulation started, but questions were not permitted once it began. In the end, users were asked for comments and thanked for their participation.

7.1.1 Usability Tests

Usability tests were devised to test our application in a realistic environment, that is, in-home cognitively impaired elders. These tests not only describe the actions and events expected to occur along the interaction with end-users, but also the time and material required for their successful completion. Table 7.1 exemplifies an usability test for evaluating the *Preparing a coffee* tutorial. Please refer to appendix D for a complete description of all the usability tests.

Test:	UT1
Task:	To start and complete the **preparing a coffee** tutorial.
Items needed:	Soluble coffee, milk or water on a vacuum bottle, sugar, a spoon, a mug.
Time expected:	3:30 minutes
Errors:	3 errors maximum
Usage scenario:	
The user initiates the application by clicking on the <TUTORIAIS> button. S/he then selects the proper category by pressing <PREPARAR REFEIÇÃO> and next clicking on the option <PREPARAR UM CAFÉ> to enter the tutorial. Once the tutorial is started, the user properly follows the instructions, answering the questions about his/her preferences to perform the activity accordingly. The user clicks on the button <SEGUINTE> any time s/he wants to move to the next step. The tutorial is considered to be finished when the user clicks on the <ACABAR> button at the last step.	

Table 7.1: Example of an usability test for the *Preparing a coffee* tutorial

7.1.2 Metrics

Usability metrics are normally used to identify what is going to be evaluated. Effectiveness, efficiency and subjective satisfactions are normally measured by observing how quickly users perform tasks, how easily they can establish proficiency, how many errors users make and how pleasant is to use the design (Kuniavsky, 2003). During the simulation, nobody was supposed to interact with end-users so that their performance was not compromised. The set of metrics used during the evaluation are listed next.

- Time spent to complete a task
- Number of errors
- Time spent to recover from errors, if any
- Rating scale of satisfaction
- Number of times user seems frustrated
- Frequency of use of the on-line help

7.2 Results

After conducting usability tests, it was important to record what had been directly observed, in addition to why such behaviour occurred according to the outcomes. Additional observations of the users gave insight on navigation difficulties and helped to acknowledge the source of the design errors so that they can be fixed quickly for continued testing.

USABILITY TEST 1					
	Time	Errors	Satisfaction	Frustration	On-line Help
Lourdes S.	2:41	0 errors	4 (out of 5)	0 (out of 5)	0 times
Alice P.	2:56	1 error (0:20)	3 (out of 5)	1 (out of 5)	0 times
Fernando P.	4:46	3 errors (1:23)	3 (out of 5)	2 (out of 5)	2 times
USABILITY TEST 2					
	Time	Errors	Satisfaction	Frustration	On-line Help
Lourdes S.	1:07	0 errors	5 (out of 5)	0 (out of 5)	0 times
Alice P.	1:16	0 errors	5 (out of 5)	0 (out of 5)	0 times
Fernando P.	2:32	1 error (0:44)	3 (out of 5)	2 (out of 5)	1 time
USABILITY TEST 3					
	Time	Errors	Satisfaction	Frustration	On-line Help
Lourdes S.	1:52	0 errors	5 (out of 5)	0 (out of 5)	0 times
Alice P.	2:10	1 error (0:16)	4 (out of 5)	1 (out of 5)	0 times
Fernando P.	2:58	2 errors (0:51)	3 (out of 5)	2 (out of 5)	1 time

Table 7.2: Outcomes of the usability tests ran for the *Preparing a coffee* tutorial

Both caregivers and users founded more practical to test the *Preparing a coffee* tutorial, so all the usability tests were focused on this activity. Table 7.2 resumes the outcomes of the three usability tests defined in section 7.1.1 and appendix D for the *Preparing a coffee* tutorial. In this table, columns refer to the metrics used to measure the user performance, while rows refer to the elderly volunteers who participated in the experimentation. If the user made any errors, column *Errors* includes the average time s/he spent to recover. Both columns *Satisfaction* and *Frustration* refer to a rating scale from 0 to 5, being 5 the highest score. Column *Help* refers to the number of times the elder used the on-line help in order to continue.

Overall, users seemed confident in their execution. Their frustration appeared when having to use the on-line help any time they hesitated about how to continue with the tutorial. Users had no difficulty in cancelling a tutorial, or acting accordingly when any of the items was missing. Certain functionalities of the interface appeared rather intuitive to our elder volunteers, such as playing a video again by clicking on its frame. The font size and the colours used for the designing helped recognition. Audio tracks proved to be an excellent way to keep the user attention on what s/he was doing. Errors made along the tests were common among end-users and mainly minor, so that the performance was not interrupted. The following list describes these errors as well as the workaround to correct them.

- **Consistency with standards.** When users completed the last step of the performance, the application congratulated them for the work done. However, it was confusing for them to click on the button *seguinte* to move to this screen once the activity was finished, being more perceptive to use the *acabar* button instead. Figure 7.1 illustrates this replacement of buttons.

Figure 7.1: Snapshot of the last step on the *Preparing a sandwich* tutorial

- **Adequacy of the technicalities.** The term *clicar* was too technical to our elderly population, so it had better be replaced by the term *carregar*. Similarly, the term *tutorial* was unknown to them so

that a phrase with the same meaning would be preferable.

- **One path instead of two.** Users (specially Lourdes S. and Fernando P.) seemed reluctant to use the navigation table, so instead they were using the *back* button. It would be more convenient to leave a unique path for simplicity, so that the *back* option should be removed.

- **Direct language.** The sentences that introduce the selection of options (*e.g.* a coffee or a sandwich) were confusing. A direct question that helped to consider the options available (*e.g.* What would you like to prepare?) would be more adequate. Figure 7.2 exemplifies this modification of the textual language.

Figure 7.2: Snapshot of the *Preparing food* tutorials

Technically, the application ran always robustly and fast enough to respond properly to the user interaction. Elders founded the interface easy to use mainly because of the graphical disposition of their elements. The equipment was simple enough to be set on a table and was not perceived as disruptive by the users at all. The quality of the media sources (audio, video) used for the steps also helped them to perform the tutorial swiftly.

8 Conclusions

We have presented an integrated approach towards building a supportive system for providing in-home assistance to older adults with cognitive and physical limitations. Our approach differs from past similar approaches with regards to two different aspects: on the one hand, we have redefined the user profile for a more **accurate personalization**, considering not only those deficits and age-related disorders that might compromise the elders' performance on daily routines. With fuzzy knowledge about the users we might undermine their residual capabilities, preventing AT from performing accurate adaptations. On the other hand, we have revised the **concept of usability** regarding interaction, developing an user interface which truly meets the needs and preferences of our target users rather than trying to match their requirements to the envisioned design. Results on the suitability of our design have clearly met the first and second objective initially defined for our work.

The experimentation phase provided useful feedback to enhance our application, not only in terms of interaction but also regarding its adjustment to the current context. Regarding the achievement of the third and fourth goal pursued by our work, we can affirm that testing our usability scenarios with real Portuguese impaired elders has proved that simple use of supportive systems might facilitate the integration of AT into caring services, diminishing constant human support. However, the fact that the uptake of these technologies by the elderly could lead to less need for caregiver support can not be stated without conducting more extensive tests. We are able to conclude that much of the success of *iTutorials* heavily depends on the personalization, since individuals with distinctive disability profiles might have a different approach to their autonomy accomplishment in the performance of basic tasks.

Although research in AT for the support of elderly population with compromised cognitive abilities is still in its infancy, specially in countries such as Portugal or Spain, the potential impact of such systems cannot be sub-estimated and will become a necessity in **alternative in-home assistance** and healthcare as society continues to age.

8.1 Future Lines of Research

There are several lines of work for improving the performance of *iTutorials* noticeably considering the context we have described. The following lines, in particular, appear to be promising.

One of the possible improvements for the future might be the design of a **tutoring agent**, so that the tracking and interaction with the user could be highly enhanced. In particular, the tutoring agent would create a cognitive model about the performance of users over time, which would be recorded for later evaluation. Thereby, the support that *iTutorials* provides could be accurately adjusted to the current status of users. This tutoring agent could also expose the user to training sessions with supervision from caregivers, so that the outcomes obtained would feed his/her cognitive model retroactively (Straalen et al., 2009).

A prospective line of work has already explained in section 4.1.2 as an approach to NLP based on the automatic generation of instructions from a lexicon of keywords. With the purpose of making *iTutorials* useful in other languages, an interesting idea would be to create a **semantic network** in order to establish relations among those terms calling the same concept in different languages (*e.g. butter* in English, *manteiga* in Portuguese, and *burro* in Italian). This repository of concepts could feed the inference engine that generates instructions in order to translate tutorials into several languages.

I Appendix

A Glossary

A.1 Medical Terms

- **Alzheimer.** The most usual form of dementia. In the early stages, the most commonly recognized symptom is memory loss, such as difficulty in recalling recently learned facts. As the disease advances, symptoms include confusion, irritability and aggression, language breakdown, long-term memory loss, and the general withdrawal of the sufferer as their senses decline. Gradually, bodily functions are lost.
- **Aphasia.** Language disorder which is presented when there is difficulty in using or understanding spoken and written language or is completely lost the ability to do either.
- **Apraxia.** Neurological disorder characterized by loss of the ability to execute skilled movements and gestures, despite having the desire and the physical ability to perform them. The sufferer is unable to map out physical actions in order to repeat them in functional activities.
- **Auditory Agnosia.** Difficulty recognising auditory cues and distinguishing speech from non-speech sounds, even though hearing is usually normal.
- **Dementia.** Progressive decline in cognitive functions affecting memory, attention, language and problem solving. Higher mental functions are affected first in the process. Especially in the later stages of the condition, affected persons may be disoriented in time (not knowing what day it is), in place (not knowing where they are), and in person (not knowing who they are or others around them).
- **Diabetes.** Metabolic disease in which a person has high blood sugar, either because the body does not produce enough insulin, or because cells do not respond to the insulin that is produced.
- **Dysphagia.** Sensation that suggests difficulty in the passage of solids or liquids from the mouth to the stomach.
- **Hemiparesis.** Paralysis affecting only one side of the body.
- **Hemiplegia.** Total paralysis of the arm, leg, and trunk on the same side of the body. Hemiplegia is more severe than hemiparesis, wherein one half of the body has less marked weakness.

- **Hypercholesterolemia.** Presence of high levels of cholesterol in the blood. It is not a disease but a metabolic derangement that can be caused by many diseases, notably cardiovascular disease.
- **Hypertension.** A cardiac chronic condition in which the systemic arterial blood pressure is elevated, being one of the risk factors for stroke, myocardial infarction and heart failure.
- **Neglect.** A condition which reduces the ability a person has to look, listen or make movements in one half of their environment.
- **Osteoporosis.** A condition characterized by a diminishing in the density of bone, decreasing its strength and resulting in fragile bones.
- **Parkinson.** A progressive nervous disease associated with the destruction of brain cells that produce dopamine and characterized by muscular tremor, slowing of movement, partial facial paralysis, peculiarity of gait and posture, and weakness.
- **Stroke.** Sudden death of a portion of the brain cells due to a lack of oxygen. It occurs when blood flow to the brain is damage resulting in abnormal function of brain. The most common symptom of a stroke is sudden weakness or numbness on one side of the body. Other symptoms include confusion, difficulty speaking, loss of coordination, fainting or unconsciousness. The effects of a stroke depend on which part of the brain is injured and how severely it is affected.
- **Visual Agnosia.** Loss of ability to recognize objects, faces and words.

B Activities of Daily Living

B.1 Activity Diagrams

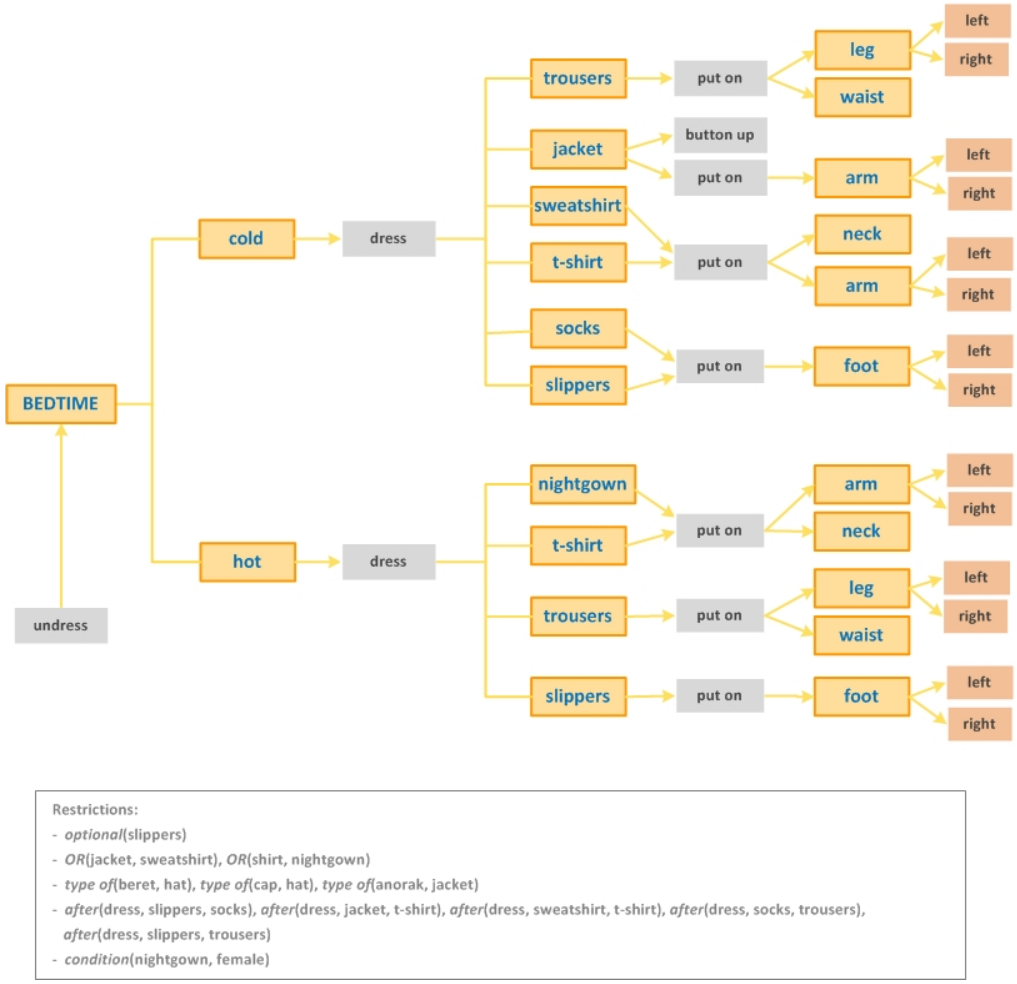

Figure B.1: Activity Diagram for the *Putting the pyjamas on* tutorial

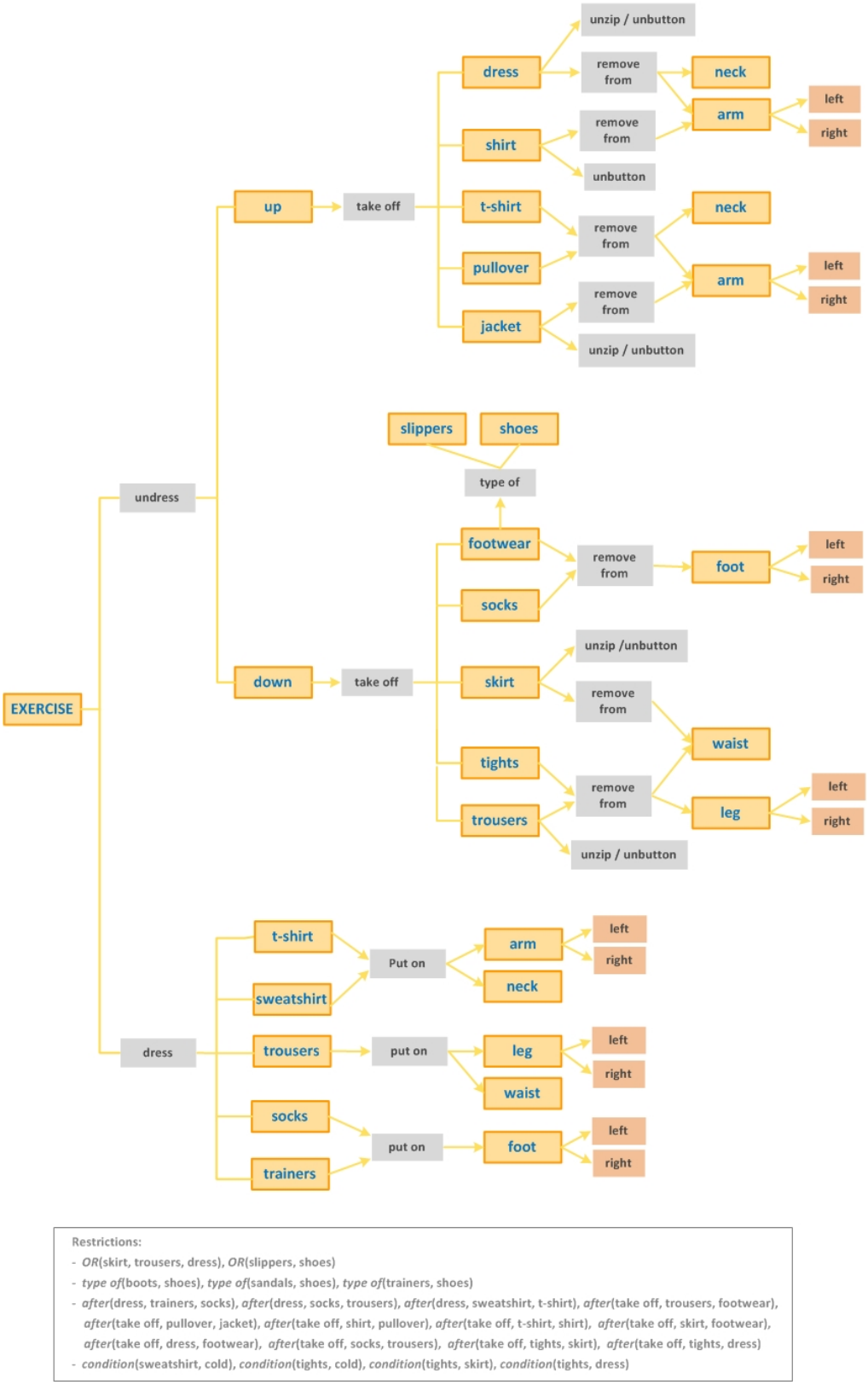

Figure B.2: Activity Diagram for the *Dressing for exercise* tutorial

B.2 Activity Work-flows in Portuguese

B.2.1 Preparing a sandwich

Nome da atividade:	PREPARAR UMA SANDES
Descrição:	Trata-se de preparar uma sandes de fiambre e queijo sem ter de cozinhar.
Ativação:	O tutorial é oferecido quando a atividade é solicitada pelo usuário ou programada pelo cuidador.
Itens necessários:	2 fatias de pão, fatias de fiambre, fatias de queijo, manteiga, uma faca, um prato.
Pre-condições:	1. Todos os itens devem estar organizados no balcão da cozinha. 2. O pão já deve estar colocado no prato.
Atividade passo-a-passo:	
G1. ITENS NECESSÁRIOS. Verifique que não falta nenhum destes itens: pão, fiambre, queijo, manteiga, um prato, uma faca. (G1, sim) Q1. Gostaria de manteiga na sua sandes? (Q1, sim) G2. ESPALHE A MANTEIGA. Espalhe uma camada fina de manteiga nas duas fatias de pão com a faca. Q2. Gostaria de queijo na sua sandes? (Q2, sim) G3. COLOQUE QUEIJO. Coloque algumas fatias de queijo no pão. Q3. Gostaria de fiambre na sua sandes? (Q3, sim) G4. COLOQUE FIAMBRE. Coloque algumas fatias de fiambre no pão. G5. JUNTE O PÃO. Junte as duas fatias de pão para fechar a sandes.	
Extensões:	(G1, não) AÇÃO: Enviar aviso ao cuidador.
Contra-indicações:	Não é indicado para aqueles usuários que sofrem de: 1. Baixa visão por motivo de segurança (*e.g.* um usuário que não consegue ver claramente as facas) 2. Tremores moderados 3. Hemiparesia que afecte a força e sensibilidade nas mãos e dedos 4. Disfagia Não use manteiga se o usuário tem colesterol alto.

B.2.2 Preparing a coffee

Nome da atividade:	PREPARAR UM CAFÉ
Descrição:	Trata-se de preparar um café sem ter de usar a cafeteira.
Ativação:	O tutorial é oferecido quando a atividade é solicitada pelo usuário ou programada pelo cuidador.
Itens necessários:	Café solúvel, leite ou água num termo, açúcar, uma colher, uma chávena.
Pre-condições:	1. Todos os itens devem ser organizadas no balcão da cozinha. 2. O termo deve conter ou leite ou água (de acordo com as necessidades do utilizador) já acequida.
Atividade passo-a-passo:	
G1. ITENS NECESSÁRIOS. Verifique que não falta nenhum destes itens: café solúvel, um termo, o açúcar, uma chávena, uma colher. (G1, sim) G2. JUNTE O LEITE. Junte o leite do termo para a chávena. G3. ADICIONE O CAFÉ SOLÚVEL. Adicione 2 colheres de café solúvel na chávena. Q1. Gostaria de açúcar com o café? (Q1, sim) G4. ADICIONE AÇÚCAR. Adicione uma colher de açúcar na chávena. G5. MEXA O CAFÉ. Use a colher para mexer o café.	
Extensões:	(G1, não) AÇÃO: Enviar aviso ao cuidador. *(se água)* G2. JUNTE A ÁGUA. Junte a água do termo para a chávena.
Contra-indicações:	Não é indicado para aqueles usuários que sofrem de: 1. Tremores leves 2. Hemiparesia que afecte a força e sensibilidade nas mãos e dedos Não use leite se o usuário tiver problemas de fígado. Não use açúcar se o usuário sofre de diabetes.

B.2.3 Dressing to go out

The following schema shows the weather categorization in Portuguese according to the temperature in degree Celsius. The resulting categories are used to discriminate the different flows of interactions and extensions patterned for the activity, considering the habits in outwear that Portuguese elders have as referred in section 4.2.3.

- if temperature $\leq$ 10 °C then it is *frio (En. cold)*
- if 10°C $<$ temperature $\leq$ 18°C then it is *fresco (En. chilly)*
- if 18°C $<$ temperature $\leq$ 24°C then it is *ameno (En. warm)*
- if temperature $>$ 24°C then it is *quente (En. hot)*

Nome da atividade:	VESTIR-SE PARA SAIR
Descrição:	Consiste em vestir-se para sair, dependendo do clima que encontrar fora de casa. Se o dia está chuvoso, o utilizador é lembrado de levar o guarda-chuva.
Ativação:	O tutorial é oferecido quando a atividade é solicitada pelo usuário ou programada pelo cuidador.
Itens necessários:	Os itens necessários podem variar de acordo com a temperatura que encontrar fora de casa. No caso de tempo chuvoso, um guarda-chuva deve ser incluído. *frio*: casaco, cachecol, luvas, calçado (sapatos ou botas), meias *fresco*: casaco, cachecol, calçado (sapatos ou botas), meias *ameno*: casaco, calçado (sapatos ou sandálias), meias *quente*: chapéu, calçado (sapatos ou sandálias), meias
Pre-condições:	1. Todos os itens devem ser dispostos na cama. 2. O calçado não deve ter laços mas pode ter fecho ou velcro. 3. É suposto o utilizador estar já vestido e com os seus chinelos.

Passos comuns

(A instrução G1 muda de acordo com a categorização do tempo)

(G1, sim) Q1. Tem os chinelos calçados?

(Q1, sim) G2. TIRE OS CHINELOS. Sentado, tire os chinelos de ambos os pés.

Q2. Tem as meias calçadas?

(Q2, sim) G3. TIRE AS MEIAS. Sentado, tire as meias de ambos os pés.

G4. CALCE AS MEIAS LIMPAS. Sentado, calce as meias limpas em ambos os pés, calçando uma de cada vez começando pela ponta do pé para cima.

G5. CALCE O SAPATO ESQUERDO. Sentado, pegue no sapato esquerdo e coloque o pé esquerdo dentro, puxando o sapato para cima com a mão de forma a introduzir o pé completamente dentro do sapato. Feche se necessário.

G6. CALCE O SAPATO DIREITO. Sentado, pegue no sapato direito e coloque o pé direito dentro, puxando o sapato para cima com a mão de forma a introduzir o pé completamente dentro do sapato. Feche se necessário.

Atividade passo-a-passo: em dia *frio*

G1. ITENS NECESSÁRIOS. Verifique que não falta nenhum destes itens: casaco, cachecol, luvas, meias, calçado.

G7. PONHA O CASACO. Ponha a manga esquerda do casaco no braço esquerdo e passe o resto do casaco por trás de si para colocar a outra manga.

(se fecho) G8. FECHE O CASACO. Feche o casaco até cima com a ajuda do fecho.

(se botões) G9. ABOTOE O CASACO. Abotoe o casaco botão por botão.

G10. PONHA O CACHECOL. Coloque o cachecol no pescoço, atravessando os dois extremos do cachecol a volta do pescoço.

Q3. Gostaria de pôr as luvas?

(Q3, sim) G11. PONHA A LUVA ESQUERDA. Coloque a sua mão esquerda no orifício na parte inferior da luva esquerda, deslize os dedos e puxe para baixo da luva até chegar ao pulso.

(Q3, sim) G12. PONHA A LUVA DIREITA. Coloque a sua mão direita no orifício na parte inferior da luva direita, deslize os dedos e puxe para baixo da luva até chegar ao pulso.

Atividade passo-a-passo: em dia *fresco*
G1. ITENS NECESSÁRIOS. Verifique que não falta nenhum destes itens: casaco, cachecol, meias, calçado.
G7. PONHA O CASACO. Ponha a manga esquerda do casaco no braço esquerdo e passe o resto do casaco por trás de si para colocar a outra manga.
Q3. Gostaria de fechar o seu casaco?
(Q3, sim) *(se fecho)* G8. FECHE O CASACO. Feche o casaco até cima com a ajuda do fecho.
(Q3, sim) *(se botões)* G9. ABOTOE O CASACO. Abotoe o casaco botão por botão.
Q4. Gostaria de vestir o cachecol?
(Q4, sim) G10. PONHA O CACHECOL. Coloque o cachecol no pescoço, atravessando os dois extremos do cachecol a volta do pescoço.
Atividade passo-a-passo: em dia *ameno*
G1. ITENS NECESSÁRIOS. Verifique que não falta nenhum destes itens: casaco, calçado, meias.
G7. PONHA O CASACO. Ponha a manga esquerda do casaco no braço esquerdo e passe o resto do casaco por trás de si para colocar a outra manga.
Q3. Gostaria de fechar o seu casaco?
(Q3, sim) *(se fecho)* G8. FECHE O CASACO. Feche o casaco com ajuda do fecho.
(Q3, sim) *(se botoẽs)* G9. ABOTOE O CASACO. Abotoe o casaco botão por botão.
Atividade passo-a-passo: em dia *quente*
G1. ITENS NECESSÁRIOS. Verifique que não falta nenhum destes itens: chapéu, calçado, meias.
Q4. Gostaria de levar um chapéu?
(Q4, sim) *(se homem)* G7. PONHA A BOINA. Ajuste a boina na sua cabeça.
(Q4, sim) *(se mulher)* G7. PONHA O CHAPÉU. Ajuste o chapéu na sua cabeça.
Extensões: em dia *frio* é *fresco*
(G1, não) AÇÃO: Enviar aviso ao cuidador.
(se botas) G5. CALCE A BOTA ESQUERDA. Sentado, pegue na bota esquerda e coloque o pé esquerdo dentro, puxando a bota para cima com a mão de forma a introduzir o pé completamente dentro da bota. Feche a bota com o fecho se necessário.
(se botas) G6. CALCE A BOTA DIREITA. Sentado, pegue na bota direita e coloque o pé direito dentro, puxando a bota para cima com a mão de forma a introduzir o pé completamente dentro da bota. Feche a bota com o fecho se necessário.
(se chove) G. LEVE O GUARDA-CHUVA. É um dia chuvoso. Não se esqueça do seu guarda-chuva.
Extensões: em dia *ameno* é *quente*
(G1, não) AÇÃO: Enviar aviso ao cuidador.
(se sandálias) G5. CALCE A SANDÁLIA ESQUERDA. Sentado, pegue na sandália esquerda e coloque o pé esquerdo dentro, puxando para cima com a mão de forma a introduzir o pé completamente dentro da sandália. Aperte as presilhas se necessário.
(se sandálias) G6. CALCE A SANDÁLIA DIREITA. Sentado, pegue na sandália direita e coloque o pé direito dentro, puxando para cima com a mão de forma a introduzir o pé completamente dentro da sandália. Aperte as presilhas se necessário.
(se chove) G. LEVE O GUARDA-CHUVA. É um dia chuvoso. Não se esqueça do seu guarda-chuva.

Contra-indicações:	Não é indicado para aqueles usuários que sofrem de: 1. Osteoporose significativa por risco de fratura. 2. Hemiparesia que afecte a força e sensibilidade nas extremidades.

C Storyboards

C.1 First draft of the user interface

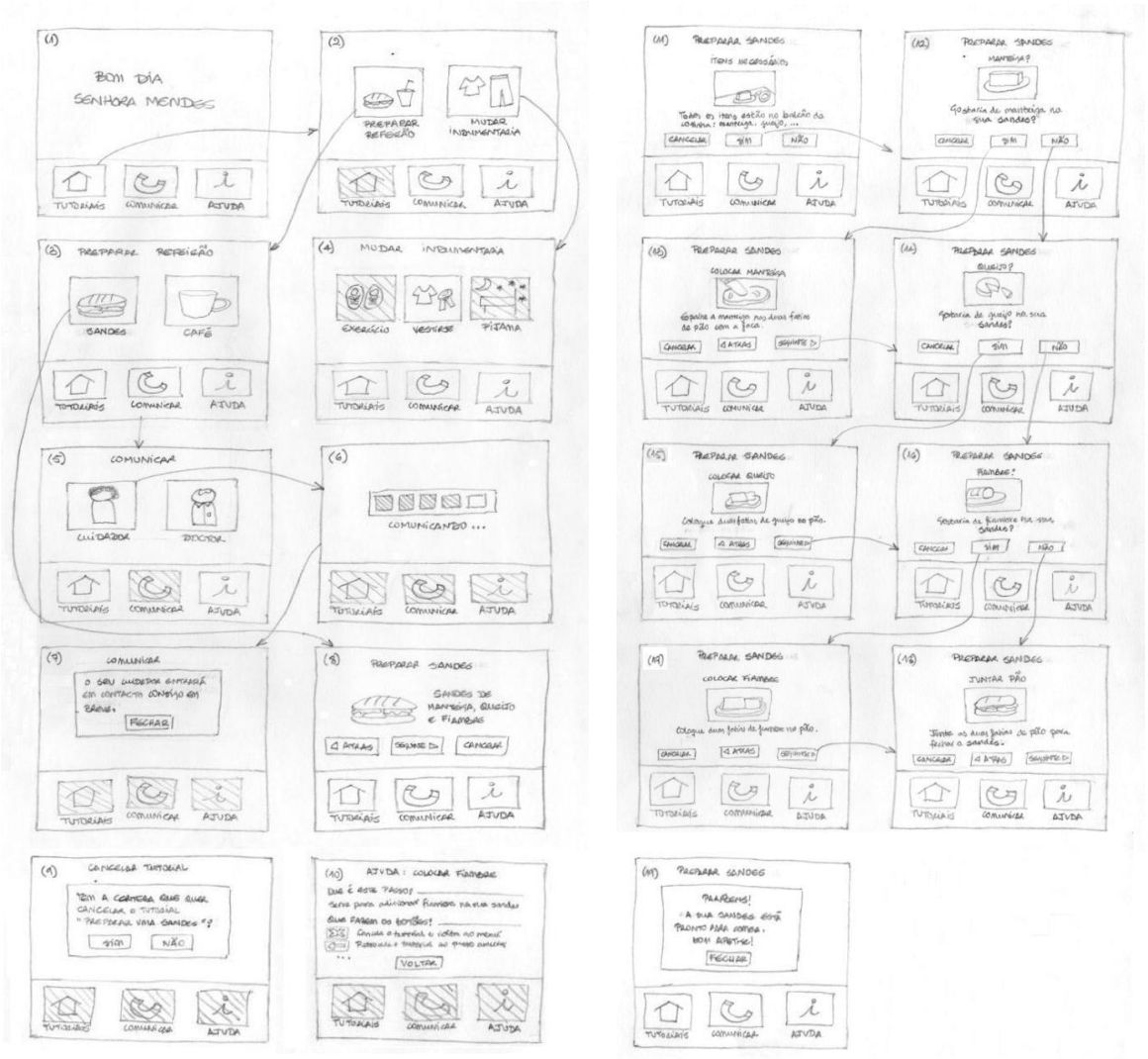

Figure C.1: First draft of the user interface

Remarks on the storyline of the first draft (numbers at the right top of each illustration will help to follow the sequence of steps):

- Button TUTORIAIS leads to screen (2). If this option is requested when the user is executing any tutorial, a question message appears so that the user confirms whether or not s/he is willing to cancel.
- Button COMUNICAR leads to screen (5). It allows the user to communicate with his/her caregiver in case of trouble. After the caregiver is warned, the application leads to the home screen (1).
- Button CANCELAR leads to screen (9). If the user decides to go ahead and cancel the tutorial, the application redirects to the home screen (1); otherwise, it goes back to the step where the user was.
- Button SEGUINTE on screen (18) leads to the final screen (19) for ending the tutorial.
- Button AJUDA leads to screen (10). Its content changes according to the step where the help was requested.

C.2 Final draft of the user interface

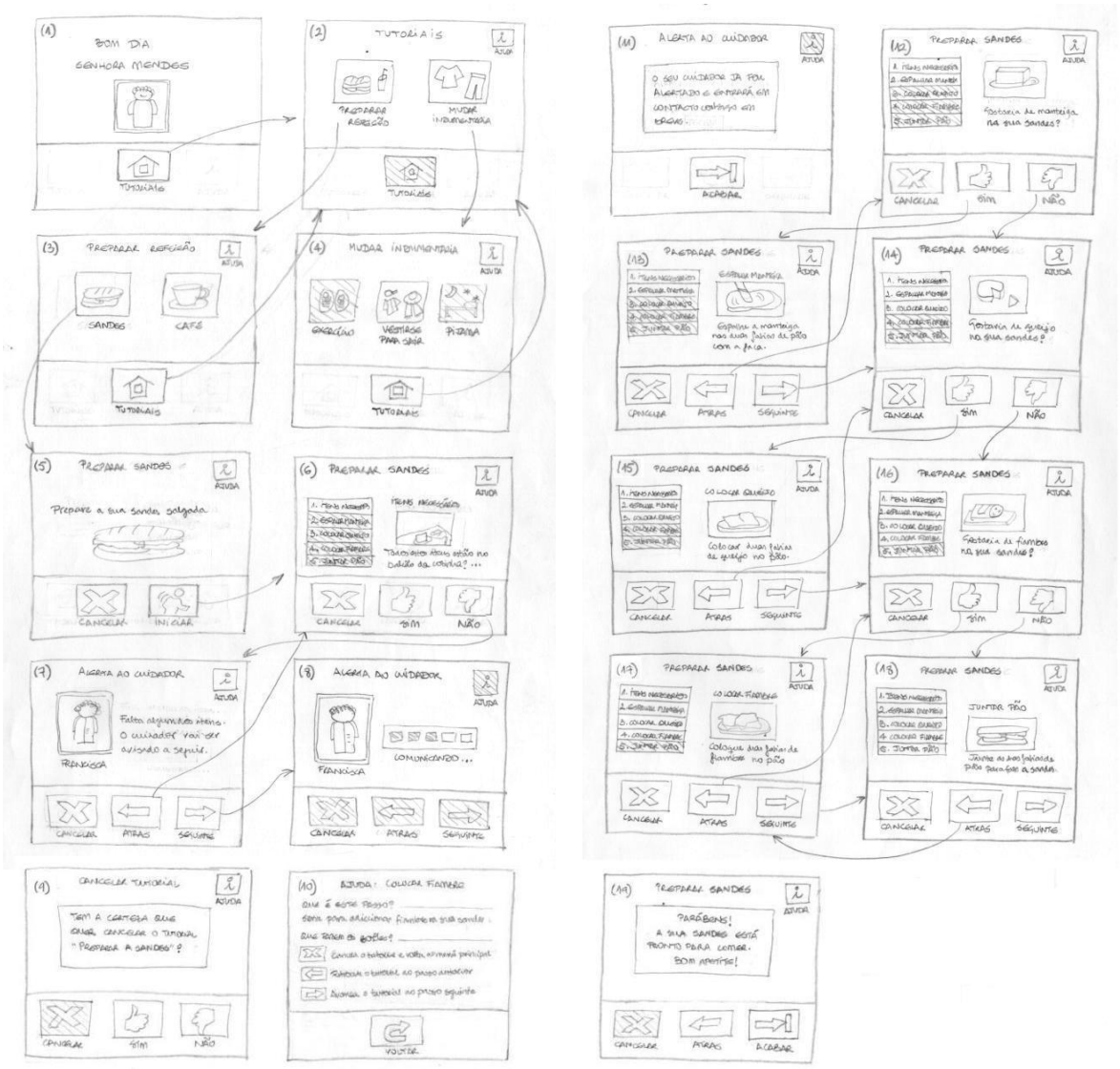

Figure C.2: Final draft of the user interface

Remarks on the storyline of the final draft (numbers at the right top of each illustration will help to follow the sequence of steps):

- Button TUTORIAIS leads to screen (2). This option is available as long as none of the tutorials is in execution.

- First instruction of any tutorial asks the user to make sure if all the necessary items are gathered nearby. If the answer is NÃO, the caregiver is warned and the tutorial ends on the screen (11). If the answer is SIM, the tutorial moves to screen (12), the following step.

- There is a navigation table available on the left side of the screen while executing any tutorial. The table shows the steps that are already completed and the steps left to finish the activity. When clicking on any of the steps completed, the application redirects to that exact point.

- Button SEGUINTE on screen (18) leads to the final screen (19) for ending the tutorial.

- Button CANCELAR leads to screen (9). If the user decides to go ahead and cancel the tutorial, the application redirects to the home screen (1); otherwise, it goes back to the step where the user was.

- Button ACABAR on screen (11) and (19) redirects to the home screen (1).

- Button AJUDA leads to screen (10). Its content changes according to the step where the help was requested.

D Usability Tests

D.1 Preparing a coffee

Test:	UT2
Task:	To start and exit the tutorial when the user realizes that the mug is missing.
Items needed:	Soluble coffee, milk or water on a vacuum bottle, sugar, a spoon.
Time expected:	1:20 minutes
Errors:	2 errors maximum
Usage scenario:	
The user initiates the application by clicking on the <TUTORIAIS> button. S/he then selects the proper category by pressing <PREPARAR REFEIÇÃO> and next clicking on the option <PREPARAR UM CAFÉ> to enter the tutorial. Once the tutorial is started, the user is asked to check if all the items are on the table. Since the mug is missing, the user answers by clicking on the button <NÃO> in order to warn the caregiver and exit the tutorial. The user confirms that s/he wants to finish the tutorial by clicking the <ACABAR> button.	

Test:	UT3
Task:	To start and cancel the tutorial during its performance. At a certain step, the user is asked to play the video again.
Items needed:	Soluble coffee, milk or water on a vacuum bottle, sugar, a spoon, a mug.
Time expected:	2:30 minutes
Errors:	3 errors maximum
Usage scenario:	
The user initiates the application by clicking on the <TUTORIAIS> button. S/he then selects the proper category by pressing <PREPARAR REFEIÇÃO> and next clicking on the option <PREPARAR UM CAFÉ> to enter the tutorial. Once the tutorial is started, the user checks that all the items are on the table and presses <SIM> to continue. Next, s/he adds the milk/water to the mug as the instruction indicates, and plays the video again by clicking on the frame. The user then presses <SEGUINTE> to continue. When it is time to add the soluble coffee, the user decides not to continue with the tutorial and s/he presses <CANCELAR> . The user confirms that s/he is certain about cancelling the tutorial by clicking on the <SIM> button.	

D.2 Preparing a sandwich

Test:	UT4
Task:	To start and complete the **preparing a sandwich** tutorial.
Items needed:	2 slices of bread, some slices of ham, some slices of cheese, butter, a knife, a plate.
Time expected:	4:00 minutes
Errors:	3 errors maximum
Usage scenario:	
The user initiates the application by clicking on the <TUTORIAIS> button. S/he then selects the proper category by pressing <PREPARAR REFEIÇÃO> and next clicking on the option <PREPARAR UMA SANDES> to enter the tutorial. Once the tutorial is started, the user properly follows the instructions, answering the questions about his/her preferences to perform the activity accordingly. The user clicks on the button <SEGUINTE> any time s/he wants to move to the next step. The tutorial is considered to be finished when the user clicks on the <ACABAR> button at the last step.	

Test:	UT5
Task:	To start the tutorial and return to a previous step.
Items needed:	2 slices of bread, some slices of ham, some slices of cheese, butter, a knife, a plate.
Time expected:	5:20 minutes
Errors:	2 errors maximum
Usage scenario:	
The user initiates the application by clicking on the <TUTORIAIS> button. S/he then selects the proper category by pressing <PREPARAR REFEIÇÃO> and next clicking on the option <PREPARAR UMA SANDES> to enter the tutorial. Once the tutorial is started, the user confirms that all the items are on the table by clicking on the <SIM> button. At a certain step, the user is asked to go back to the first instruction, so s/he either presses the corresponding button on the navigation table at the left or moves backwards by clicking on the <ATRÁS> button. The tutorial is considered to be finished when the user clicks on the <ACABAR> button at the last step.	

E Economic Analysis

E.1 Temporal Analysis

We analyse below the time spent in each of the project phases for developing *iTutorials* along with the breakdown of tasks for each phase.

INTRODUCTION (4 hours/day)	days	hours
Definition of the scope and purpose	5	20
Collection of data from the previous work for the *SHARE-it* project	5	20
Thorough research on the current State-of-the-Art	15	60
Total	25	100

SPECIFICATION (8 hours/day)	days	hours
Definition of the target population and the context	4	32
Interviews with experts	3	24
Description of the ADLs and the problem scenarios	5	40
Analysis of the system requirements and use cases	4	32
Total	16	128

DESIGN (10 hours/day)	days	hours
Description of the conceptual model	6	60
Development of a tutorial model for automatic step generation	3	30
Design of the activity diagrams and definition of their restrictions	10	100
Description of the activity work-flows	5	50
Definition of the user profiling and the medical terms in glossary	4	40
Description of the mechanisms planned for contextualization	2	20
Translation of the activity work-flows into Portuguese	3	30
Total	33	330

PROTOTYPING (10 hours/day)	days	hours
Heuristic evaluation of the previous user interface	2	20
Iterative design and review of the storyboards and the interaction scenarios	5.5	54
Making of a low-fidelity prototype	1.5	12
Evaluation of the prototyped user interface with volunteers	2	20
Total	11	110

IMPLEMENTATION (10 hours/day)	days	hours
Study of the most suitable programming languages and tools for development	0.5	5
Coding of the user interface module	18	180
Coding of the agent technology module	8	80
Individual test of each module	1	10
Deployment of the modules and DLA connection	0.5	5
Media recording (audio and video)	3	30
Total	31	310
TESTING (10 hours/day)	days	hours
Definition of the testing methodology and the usage scenarios	2	20
Iterative experimentation of *iTutorials* with elderly volunteers	1	10
Analysis of the outcomes and redesign of the application, if necessary	2	20
Total	5	50
DOCUMENTATION (10 hours/day)	days	hours
Writing of the conclusions and future lines of research	0.5	5
Report on the temporal and economic analysis for the present work	0.5	5
Writing the summary paper	2.5	25
Review and update of the current Master's thesis report	1.5	15
Total	5	50
TOTAL SUM	128	1098

Table E.1: Time breakdown of tasks for the development of *iTutorials*

The total amount of days dedicated to develop the present work results in 128 days, which is equivalent to 6 months working 8 hours per day in average. In comparison to the 5 months estimated when the proposal for the Master's thesis was presented, this substantial increase can be justified in terms of redefinition of the scope, time spent on interviewing experts, iterative design of the user interface, and testing with real Portuguese end-users. All this time was very profitable so that only small modifications were necessary in the last phases to comply with the system requirements.

E.2 Economic Analysis

There are three important aspects to take into consideration for the economic analysis:

- *Hardware.* The development and testing of *iTutorials* was carried out in the same computer. This computer was powerful enough to comply with those requirements related to operability, such as fast display of contents.

- *Software.* It was intended to use as many open source tools as possible, since they can be downloaded for free and installed easily. Hence, applicable expenses from the acquisition of software programs were non-existent.
- *Human Resources (HR).* These expenses are those applicable to tasks performed by an analyst, a programmer and a media technician.

HARDWARE	expenses
PC Intel Core i3-330UM Processor (3MB cache, 1.20 GHz) 4GB RAM Memory	900 €
Total	900 €

SOFTWARE	expenses
TexMaker Cross-Platform LaTeX Editor + MiKTeX	0 €
Gantt Project	0 €
CMaps Tools + Dia Diagram Editor	0 €
Eclipse Classic 3.5.1 + Java SE Development Kit 6	0 €
JADEX BDI Agent System 2.0	0 €
Java Media Framework 2.1.1 + JMStudio	0 €
Fobs 0.4.2 + Plugin Javamp3 1.0	0 €
Audacity 1.3.13 + Windows Movie Maker	0 €
Total	0 €

HUMAN RESOURCES	expenses
Analyst (Specification + Design + Documentation)	(60 €/ 603h)
Programmer (Prototyping + Implementation + Testing + Documentation)	(30 €/ 465h)
Media Technician (Video and Audio Recording)	(45 €/ 30h)
Total	51480 €

TOTAL SUM	52380 €

Table E.2: Applicable expenses for the acquisition of hardware, software and HR

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